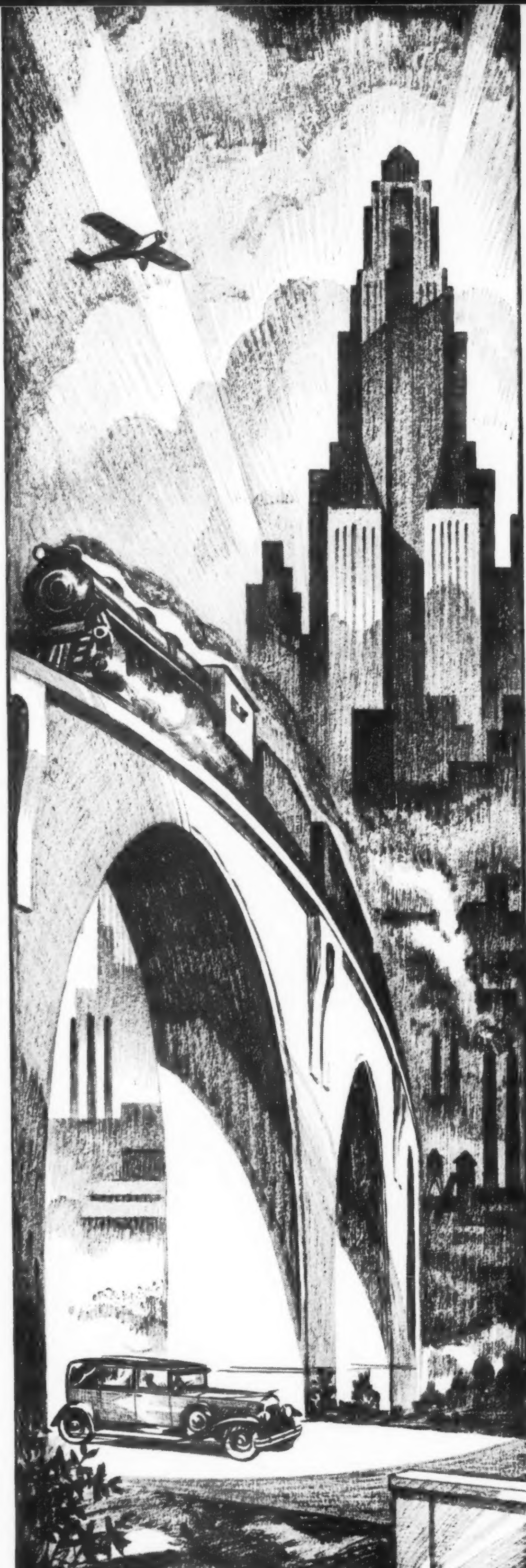

The CRUSHED STONE JOURNAL

PUBLISHED QUARTERLY

In This Issue

June · 1944

Official Publication
NATIONAL CRUSHED STONE ASSOCIATION

Technical Publications

of the

National Crushed Stone Association, Inc.

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The Crushed Stone Journal

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THE CRUSHED STONE JOURNAL

WASHINGTON, D. C.

Vol. XIX No. 2 PUBLISHED QUARTERLY JUNE, 1944

Report on Construction of Bituminous Surface Treatment Test Sections

New York State Route 9-W at Bethlehem Center, South of Albany, September 18 to 25, 1942

By **A. T. GOLDBECK**
Engineering Director,
National Crushed Stone Association.

Introduction

THE present report is intended to cover the construction procedure and other relevant details in connection with the building of fifteen different bituminous surface treatment test sections, a few of which contained variations which have been recorded in detail. These sections were constructed on New York State Route 9-W, south of Albany, near Bethlehem Center and extended from a point approximately 2½ miles south of the intersection with New York State Route 32 to a point approximately a quarter of a mile north of that intersection. The work was done by a regular maintenance force of the State under the administrative direction of District Engineer J. W. Holler, through his assistant, Mr. Edward Delahanty with Mr. Oscar Widstrand as Observer and Recorder for the State Highway Department. The technical details of the work were directed by the writer assisted by J. E. Gray, Testing Engineer, of the National Crushed Stone Association.

Two different kinds of coarse aggregate were used, iron ore tailings resulting from the extraction of iron ore and crushed limestone produced at South Bethlehem, N. Y. Various sizes of these aggregates and their combinations were used as will be noted later and, toward the latter end of the experiment, re-crushed or cubical limestone was used in place of the limestone as ordinarily produced. Previous tests by the National Crushed Stone Association laboratory have indicated that the iron ore tailings have a Los Angeles abrasion loss of 35.9 percent and the limestone of approximately 21 percent. This information is given here at this time for possible later reference in connection with the service behavior of these respective materials.

The bituminous material used throughout the experiment was tar supplied to conform with the New York Highway Department specification, item 73a, Grade B. This grade corresponds with the American Association of State Highway Officials designation RT-8. It has a float test requirement at 32° F. of 80-120. It is suitable for application to the road at temperatures varying from 150 to 225° F.

The road to which the surface treatments were applied was a 16-ft. concrete pavement probably 25 years old, built without a center longitudinal joint. The pavement was not badly scaled, but in spots there was frequent cracking. Especially toward the northern end, south of the intersection with Route 32, the pavement had been given considerable surface patching with Colprovia and, in addition, the entire length had been widened with concrete strips on each side. These strips were not continuously at the same level as the concrete pavement because of differential settlement and, consequently, the final surface of the bituminous treatments was not as smooth as might be desired, nor could the surfaces

be made uniform in many cases, because of the impossibility of uniform rolling, the roller wheels spanning the valleys and riding on the high spots in the original pavement. A more favorable base condition could have been secured by patching the low spots in the original pavement and it is under-

FIGURE 1.
DISTRIBUTOR APPLYING TAR.

stood that this would have been done had the present shortage of maintenance materials not prevented. The width of pavement treated was 20 feet south of the intersection with Route 32 and 24 feet north of that intersection.

Purpose of the Investigation

From the viewpoint of the writer, representing the New York crushed stone producers, the purpose of the investigation was to make a field study of various methods for surface treating concrete pavement using crushed stone cover, with the idea of developing a method or methods which would be entirely satisfactory to the State Highway Department from the standpoint of both durability and skid-resistance. Duplicate sections using tailings were constructed in the same manner as with crushed stone to study the relative behavior of these two aggregates. Thus a determination might be made if there is any outstanding difference which might warrant the exclusion of one or the other of these aggregates from particular types of construction, taking into consideration the technical results achieved and bearing in mind, also, the relative delivered costs of these different materials. Above everything else, however, this investigation is a technical study from which it is hoped to obtain facts showing how crushed stone can best be used in the surface treatment type of concrete pavement maintenance.

Traffic Conditions

Traffic amounting at times to 60 to 80 vehicles per hour each way was not diverted from the road during the construction of the test sections and this fact in certain cases no doubt resulted in some deleterious effect on the newly constructed surface treatments. An attempt was made to allow three hours to elapse before permitting the traffic to be turned on the new sections, the traffic in the meantime operating on the opposite half of the road. It sometimes happened, however, that the curing period was less than three hours and, in one case, on the northern eastern half of Section 13, traffic was allowed to operate immediately while the opposite side was being constructed. These facts concerning traffic should be borne in mind upon viewing the photographs accompanying this report. Questions of material supply, the amount of tar remaining in the distributor, the necessity of keeping traffic moving,—all had a controlling influence on the time at which the various test sections could be opened to traffic.

The stone generally was glistening wet when used and the tailings were damp. Upon being spread, however, both aggregates generally rapidly dried out and except in those cases where traffic had to be turned on the surface within one hour, moisture had dried from the surface at least, although probably not from that portion in contact with the tar. Much of the traffic slowed down very little in operating

FIGURE 2.
SPREADER APPLYING AGGREGATE.

over the new sections and from certain of the sections some of the aggregate, both stone and tailings, was displaced.

State Specifications for Aggregate Sizes

Various sizes of aggregates were used in the pres-

ent investigation which were supposed to comply with the following State specification:

SIZES OF STONE, GRAVEL AND SLAG

	Percentages by Weight Passing the Following Square Openings				
Sizes:	1⅞"	1"	½"	¼"	⅛"
1A	---	---	100	90-100	0-15
1	---	100	90-100	0-15	---
2	100	90-100	0-15	---	---

Equipment Used in Construction

1. *Distributor.* (*Fig. 1.*) The distributor was of a standard type. It was equipped with heating apparatus and thermometer for controlling the temperature of the tar and it was provided with an auxiliary tachometer wheel for accurately registering the speed of the vehicle and thus controlling the amount of tar per square yard of surface. Its capacity was 1100 gallons. The operator had had long experience in distributor operation. There was no easy way of verifying the actual quantities of tar distributed, but the fact that the distributor tank became exhausted at almost identically the spot this should have taken place is fairly good evidence that the rate of tar distribution was, in general, exact, with perhaps some variation at the beginning and ending of the test sections and in one or two sections at the middle where the tank became empty. It is suggested that

FIGURE 3.
ROLLING.

the test sections exclude 25 feet at each end to allow for possible non-uniformity due to uncontrollable variations both in tar and in spreading of aggregate and similarly, for the same reason, certain spots near the center of several sections should be excluded.

The spreader bar was ten feet long to cover half of the road, except in the northern end of the test section where the road was 24 feet wide, in which case the spreader bar was increased to a length of 12 feet, by an addition to the outer end next to the shoulder of the road.

2. *Spreader.* (*Fig. 2.*) The spreader consisted of a hopper, extending across a 10-foot width, into

FIGURE 4.
LIGHT BROOM DRAG ON ROLLERS AIDS IN DISTRIBUTING AGGREGATE.

which the stone was fed from the back of the truck. It was supported on pneumatic tired wheels which actuated a roller for feeding the stone through the spreading orifice. The width of spreading orifice was controlled by pressure on what in effect is a steel broom, ten feet wide, bearing against the opposite edge of the orifice. This spreader in its condition as used was not entirely satisfactory when the material was graded in size. It worked fairly well, however, with material of uniform size, but with the graded material more spotting was necessary by hand methods than with small size cubical material. The spreader was always followed by two trucks containing aggregate of the same size as distributed by the spreader. (Fig. 5.) This aggregate was used for spotting purposes. (Fig. 6.)

The procedure (Figs. 7 and 8) in determining the desired setting of the spreader box was to make an estimate of the proper setting, then make a short trial run, spreading the aggregate over a sheet of building paper 1 yard wide and about 10 feet long. The aggregate on this paper was observed to get an idea of its appearance and it was then weighed by the use of a spring balance to obtain the weight per sq. yd. If spotting was necessary on this area to make the spread uniform, the required spotting was given before weighing the aggregate. As a result of such tests, the desired setting of the spreader and desired appearance of the aggregate as spread to the proper

amount were obtained. There were no other facilities for determining the quantities of aggregates used per square yard.

3. *Rollers.* (*Fig. 3.*) The rollers were two in number of the 3-wheel combustion engine type, one a

FIGURE 5.
TWO TRUCKS FOLLOW SPREADER FOR "CHIPPING".

7-ton and the other a 10-ton roller. Each roller was provided with a light steel broom (Fig. 4.) which could be raised or lowered at will.

The entire crew was evidently experienced in surface treatment work and they did their portion of the work in a very satisfactory manner. Although a record was made of the time of the day at which the sections were constructed it was soon found impossible to keep a record of the time intervals necessary for performing the different classes of work in connection with each section. There was not quite enough truck equipment available to keep the spreader in constant operation and, furthermore, in view of the experimental nature of the sections and the necessity for frequent changes in spreader setting there was much delay in making measurements to insure that the right quantities were being spread. Time studies on the various sections were therefore of no value for predicting what the relative costs might be if these same sections were to be built over long stretches of road and with pre-determined settings of the spreader and a pre-knowledge on the part of the operator as to what the sections should look like.

Comments Regarding the Individual Test Sections

Sections 1 to 13, inclusive, are 1000 ft. long; Section 14 is approximately 750 ft. with a break near the center where Route 32 crosses Route 9-W.; Section 15 is also about 750 ft. long.

Sections 1, 2, 3 and 4. These first four sections constitute studies in the lightest form of surface treatment. The ideal condition to be finally established in such light treatments using one size aggregate is to have just the right amount of bituminous material for proper adhesion of the cover and just enough of adhering, uncrushed cover material to entirely cover the bitumen and no more. More cover material than necessary is really harmful, for not only does it grind under traffic, but this excess also tends to grind the material which is adhering to the bitumen. This grinding action is deleterious to the final surface. Another very important factor in connection with such thin types is to roll just enough to seat the cover material in place and no more. Nothing of value is accomplished by extra rolling, but, on the other hand, very serious harm can be done because extra rolling merely crushes the cover material. Excessive rolling is especially harmful to limestone for it results in a smooth surface because of the reduced size of the aggregate and also because the powder thus formed mixes with the bitumen and creates a slick spot.

Section 1, West, was the first section built and it was rolled excessively. The roller men, until stopped, merely followed their usual practice with work requiring heavier treatments. Section 1, West, was rolled eight or ten times. On the other hand, Section 1, East, which was identical in character was rolled only twice. This lighter rolling, combined with the fact that only 21+ lb. cover stone was used

FIGURE 6.
"CHIPPING" OR "SPOTTING" BARE PLACES.

instead of 25+ as on the West side, produced an ideal surface on the East side whereas the stone on the West side was crushed excessively due to over-rolling.

Thirty pounds of cover material, as used in Sec-

FIGURES 7 AND 8.
MEASURING RATE OF APPLICATION OF AGGREGATE

tions 2 and 3, is really excessive in that it is more than necessary to cover the bitumen and, therefore, a portion of it becomes ground under traffic, displaced by traffic and aids in grinding the underlying stone or tailings.

A comparison of Figs. 9 and 10 will show very definitely the points which are brought out above. Note the very much finer appearance of the stone in Fig. 9 as compared with that in Fig. 10. Rolling was stopped on Section 1 West because it was noticed that this stone was being crushed excessively. There was very little cover material displaced from Sections 1 and 4 using a theoretical 25 lb. of cover stone No. 1, or tailings No. 1. The lessons to be learned from these first four sections are:

1. Don't use an excess of cover, not more than 25 lb.
2. Don't over-roll. Avoid crushing the cover. Two or three passes, just enough to seat the cover is enough rolling for such thin treatments.

Sections 5 and 6 were intended to simulate one of the New York State present methods of single surface treatment, using 0.3 gal. of tar and 40 lb. of cover material composed of 1/3 No. 2 and 2/3 No. 1 size. This material, graded in size, did not spread uniformly with the type of spreader used and had to be spotted generously. There was a tendency for the finer material to seek the bottom of the layer as spread. The limestone section No. 5 was rolled ten times and the tailings section four times. More rolling than this on the tailings section would tend to crush the No. 2 size and there seemed to be no reason for using this large size and then crushing it down to something smaller. When a mixture of No. 2 and No. 1 stone is used as in Section 5, unless the large stone is crushed by rolling it is inevitable that a knobby surface will result. A great deal of the No. 1 stone was displaced under traffic thus exposing the No. 2 material.

The character of the resulting surface in the lime-

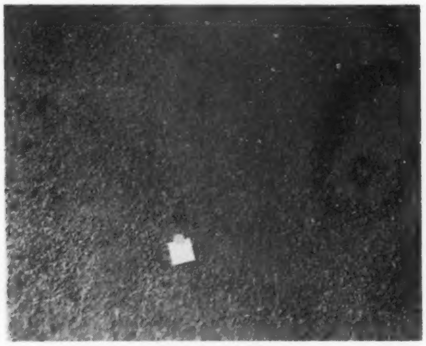


FIGURE 9—STONE.
SECTION 1 WEST—ROLLED EXCESSIVELY.
AFTER 7 DAYS OF TRAFFIC.

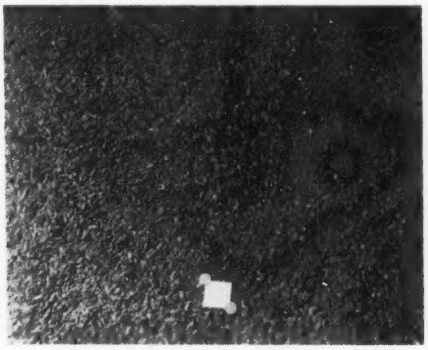


FIGURE 10—STONE.
SECTION 1 EAST—LIGHT ROLLING.
AFTER 7 DAYS OF TRAFFIC.

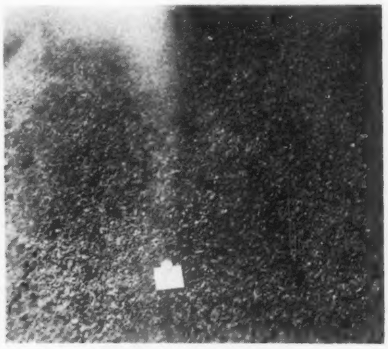


FIGURE 11—TAILINGS.
SECTION 2 WEST. AFTER 7 DAYS OF TRAFFIC.

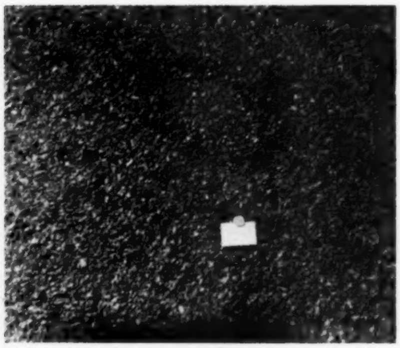


FIGURE 12—TAILINGS.
SECTION 2 EAST. AFTER 7 DAYS OF TRAFFIC.

FIGURE 13—STONE.
SECTION 3. AFTER 7 DAYS OF TRAFFIC.

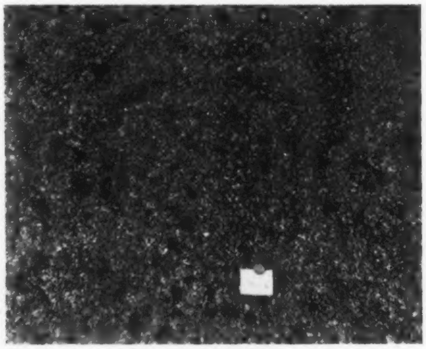


FIGURE 14—TAILINGS.
SECTION 4. AFTER 7 DAYS OF TRAFFIC.

stone section is shown in Fig. 15 and the tailings surface in Fig. 16. A rough texture results with both materials. Much cover material was displaced by traffic and this seems undesirable for this displacement not only disturbs the balance between the amount of tar and the amount of cover material, thus leading to a possible deficiency of cover material later on, but, moreover, advantage is not obtained from the full amount of cover material originally applied to the surface.

In sections 7 and 8 a New York State method of double surface treatment, 0.4 gal. of tar was followed by 40 lb. of 1/3 No. 2 and 2/3 No. 1 size mixed together. Traffic was turned on the base course after rolling and curing and after several days under traffic another treatment of tar was applied at the rate of 0.25 gal. followed by 25 lb. of No. 1 stone. As in the case of the base course, there was displacement of a part of the cover which was thrown off to one side of the road by traffic. Stone Section 7 is shown in Fig. 17 and tailings Section 8 in Fig. 18. Both of them are smoother than the single surface treatment in the preceding sections, but both of them presented an anti-skid surface at the time the picture was taken after a few day's traffic.

Sections 9 and 10 are unique in that the No. 2 stone was first spread on the concrete before surface treating it with bituminous material, then 0.45 gal. of tar was applied, followed by a cover of 30 lb. of 80 percent No. 1 and 20 percent No. 1 A stone, mixed. The purposes of this method of treatment contrasted with that used in Sections 5 and 6 were, first, to attempt to have the No. 2 stone more uniformly distributed over the road surface; second, to have the tar in a more uniform layer when the finer cover is applied due to the impedance offered by the No. 2 stone against flow, and, third, to have the No. 2 stone directly in contact with the concrete pavement instead of having it rest on smaller stone with the possibility of not being cemented down and thus being more readily displaced under traffic. Examination showed tar under the No. 2 stone in many cases and only partially under in others. It is believed, however, that the concrete surface will ultimately be covered with tar.

Construction views in connection with this method

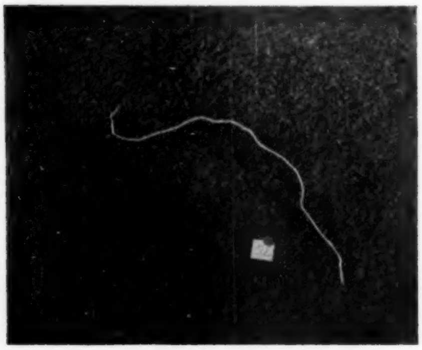


FIGURE 15—STONE.
SECTION 5. AFTER 6 DAYS OF TRAFFIC.

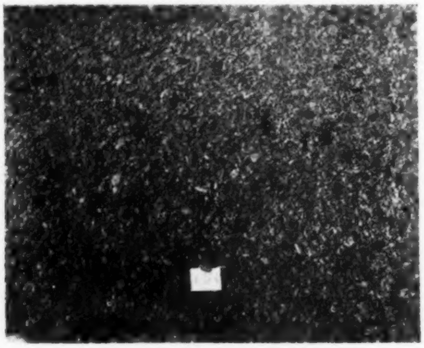


FIGURE 16—TAILINGS.
SECTION 6. AFTER 6 DAYS OF TRAFFIC.

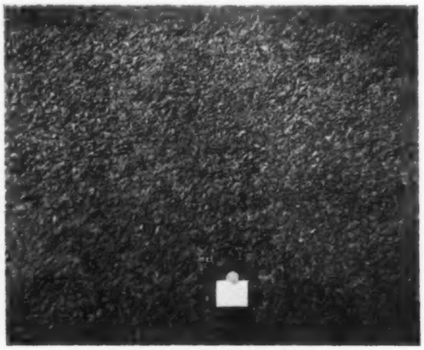


FIGURE 17—STONE.
SECTION 7. AFTER 4 DAYS OF TRAFFIC.

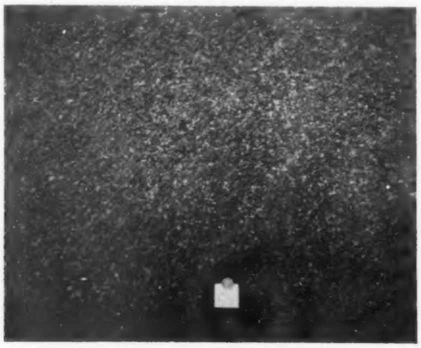


FIGURE 18—TAILINGS.
SECTION 8. AFTER 4 DAYS OF TRAFFIC.

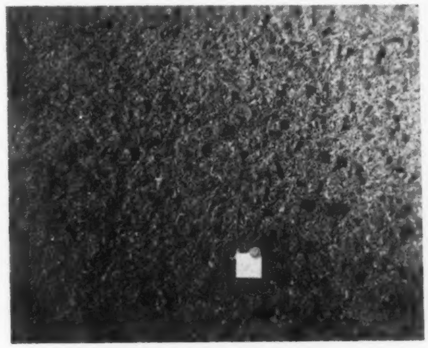


FIGURE 19—STONE.
SECTION 9—AFTER 4 DAYS OF TRAFFIC
(Compare with Figure 23)

of treatment are shown in Figs. 20, 21 and 22. Fig. 20 shows the stone in place on the concrete base before distributing the tar; Fig. 21 after the application of the tar; and Fig. 22 after the final application of the mixture of Nos. 1 and 1A stone. Fig. 19 shows the appearance of the stone section several days after it was opened to traffic and Fig. 23 that of the tailings section. It will be noted that both of these sections present a very "toothy" or jagged surface which should be exceedingly non-skid. Such a surface surely is not recommended for general use, but it might have very great usefulness for special application such as on grades, or on sharp curves and at dangerous intersections or on stretches of road involving all of these hazards. It would seem that such a surface would accelerate tire wear. In all probability, however, this jaggedness will disappear to some extent in time and the surfaces thus become less abrasive.

Sections 11 and 12 were built as a type of double surface treatment using the same general method as in the preceding single surface treatment sections. Twenty pounds of stone No. 2 were applied to the concrete first, then, 0.35 gal. of tar, then 20 lb. of No. 1 stone which was rolled lightly, then 0.15 gal. of tar followed by 10 lb. of No. 1 A stone. After this final application, the rolling should be heavy in order to compact the whole mass together and obtain density and stability.

This method of construction gives an excellent appearing surface which is non-skid and which can be made smooth riding. Perhaps additional study is needed to determine the right quantity of No. 2 and No. 1 stone to obtain the very best results. The advantage in this method of construction is that there is no waste of material whatever. All of it is retained on the road surface and, furthermore, the treatment can be completed before the road is opened to traffic and while all of the equipment is at that particular location. It is necessary that the No. 1 stone be used in sufficient quantity to over-fill the voids between the No. 2 stone. Thus the roller will not ride on the No. 2 stone and prevent adequate compression of the No. 1 material. The appearance of stone Section 11 is shown in Fig. 24, and that of the tailings section in Fig. 25. Both surfaces have a smooth, uniform, but non-skid appearance.[1]

Section 13 is a double surface treatment requiring, first, 0.25 gal. of tar followed by 25 lb. of No. 1 and No. 1A stone. This was rolled lightly, then immediately given 0.25 gal. of tar followed by 25 lb. of No. 1 and No. 1A stone mixed. This is one of the simplest double surface treatment methods used and, if allowed to cure adequately, it should give excellent results.

Attention is called to the fact that the base course of the east side, northern half of Section 13 was completed late on September 21 and the surface course on this particular portion was not laid until the next morning, September 22. Traffic probably operated over the base course that night in from one to one and one-half hours after its completion and the next morning traffic ran over the surface course almost immediately after its completion. Thus, this northeast quarter of Setcion 13 was subjected to abnor-

[1] Additional study has been given to this method of double surface treatment in the Circular Tract of the National Crushed Stone Association and as a result, the following sequence of operations and quantities are recommended:

RECOMMENDED SEQUENCE OF OPERATIONS

1. First spread in a uniform manner 30 lb. per sq. yd. of No. 2 stone (½ to 1 in. size).
2. Treat with .2 to .3 gal. per sq. yd. of RC-5, or equivalent tar.
3. Spread uniformly 30 lb. per sq. yd. of No. 1 stone (¼ to ½ in. size).
4. Roll very lightly (about one or two passes).
5. Treat with .3 to .4 gal. per sq. yd. of RC-5, or equivalent tar.
6. Cover with 10 lb. per sq. yd. of No. 1A stone (⅛ to ¼ in. size).
7. Roll until adequate compaction is obtained, but not to the extent of crushing the aggregate excessively (about 10 to 12 passes of the roller).

mally severe conditions due to the practical absence of curing before the operation of traffic. In consequence, considerable cover stone probably was displaced by traffic from both the base and surface courses, thus leaving too little residual stone to properly blot up the tar. The remaining three-quarters of Section 13 which was built and cured as intended before being subjected to traffic did not show excessive fatness. Perhaps the effect of traffic on this surface is useful in demonstrating the strong desirability of providing adequate curing periods, and also to the desirability of completing both courses before subjecting the surface to traffic. Perhaps, also, less tar could have been used; likewise, the quantities in the respective four applications are worth further study. There is no counterpart to Section 13 constructed with tailings, because the tailings were not immediately available in the sizes desired.

The remaining test sections were built entirely with limestone which was re-crushed to make it cubical in shape. Section 14 West was intercepted at about the middle by State Route No. 32. The southern portion of Section 14 is 464 ft. long, the northern portion is 361 ft. and the intersection, not included in the test, is 183 ft. long.

The West side, both north and south of the intersection was covered with 0.3 gal. of tar then with 40 lb. of 1/3 No. 2 and 2/3 No. 1 stone, rolled, and was then opened to traffic after only about 1 hour's curing due to the lateness of the day and to the danger of maintaining traffic control after dark. Section 14 West was built in the same manner as Section 5 except that re-crushed stone was used in Section 14 and ordinary stone in Section 5. A considerable amount of loose stone was displaced by traffic from Section 14 just as in Section 5, leaving the No. 2 stone projecting up beyond the general level of the surface and thus making for a jagged appearance which, according to the photographs at least, is even more jagged than Section 5 as shown in Fig. 15. Such a jagged surface must surely be objectionable to the traveling public and is not recommended for general use, but only for very special purposes such as before noted.

Section 15 was built with re-crushed limestone in the same manner as Section 9. Twenty pounds of re-crushed limestone No. 2 were first spread on the concrete surface, then treated with .45 gal. of tar and then with 30 lb. of No. 1 and No. 1A stone mixed. This was rolled and after curing, was opened to traffic. The upper portion of the layer of small sized stone was not in contact with the tar and therefore was displaced under traffic. A view of the side of the road showing the amount of stone whipped off by traffic is given in Fig. 31, and there is a general view of Section 15 in Fig. 32. A detail view showing the appearance of the surface is given in Fig. 30. This is a rough surface which probably is undesirable from the traffic standpoint. These extremely jagged surfaces are in danger of ravelling to some extent and in general are not recommended.

Modifications were made of Sections 14 and 15 which are shown in detail on the large table. They are in the form of double surface treatments made for the purpose of giving a more desirable surface which should be more durable and should have the further advantage of making full use of all of the material applied to the road instead of losing it due to displacement and grinding by traffic.

SINGLE SURFACE TREATMENT IN WHICH THE AGGREGATE IN THE FIRST COURSE IS APPLIED BEFORE THE TAR.

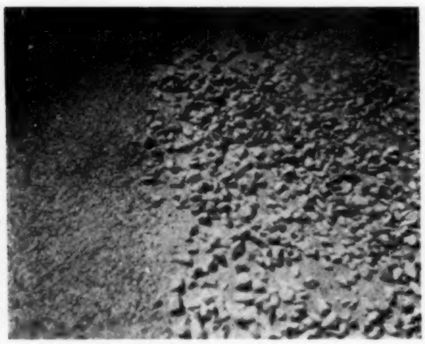


FIGURE 20.
NO. 2 STONE ON BASE AT RATE OF ABOUT 20 LB. PER SQ. YD.

FIGURE 21.
NO. 2 STONE AFTER APPLICATION OF TAR AT THE RATE OF 0.45 GAL. PER SQ. YD.

FIGURE 22.
AFTER APPLICATION OF NO. 1 AND NO. 1A STONE ON TAR-COATED NO. 2 STONE.

FIGURE 23—TAILINGS.
SECTION 10. AFTER 2 DAYS OF TRAFFIC.
(Compare with Fig. 19)

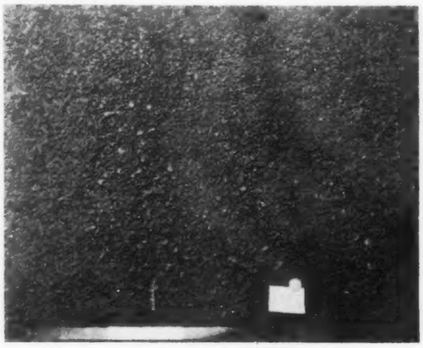


FIGURE 24—STONE.
SECTION 11. AFTER 3 DAYS OF TRAFFIC.

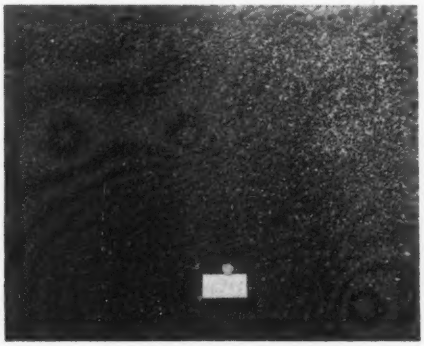


FIGURE 25—TAILINGS.
SECTION 12. AFTER 2 DAYS OF TRAFFIC.

Conclusion

It is too early and it is not the purpose of this report to draw any conclusions or to make any predictions as to the probable behavior of these various test sections. In the description of the sections, remarks were included to emphasize some of the points which seemed to disclose themselves during construction. It will do no harm to repeat some of the most important indications revealed during this construction period. They are as follows:

1. On thin surface treatments, such as Sections 1 to 4 inclusive, the aim to be accomplished is to construct a surface covered with just enough cover stone and no more, rolled just enough to make this stone adhere to the tar without crushing the cover material. Over-rolling is very harmful; it produces excessive powder in a limestone cover and greatly reduces the size in the tailings cover. Just enough aggregate to cover the surface and only one or two passes of the roller are required for the best results.

2. In the case of double surface treatments which are constructed in a continued sequence of operations until completion, before opening to traffic (Sections 11, 12, 14E and 15NE), sufficient rolling for adequate compaction is necessary, care being taken however not to crush the surface aggregate unduly.

3. It would seem well to use a method of construction, whether it be for single or for double surface treatments, which will result in no loss of cover material or at least a minimum of loss. An excess of cover material grinds the material immediately beneath it and thus has a doubly deleterious effect. The excess is also lost by displacement due to traffic.

4. The desirability of adequate curing has been amply demonstrated. Traffic should not be turned on surface treatments immediately. Three hours, however, seemed to be ample time, but this period will vary with circumstances.

It is again recommended that in examining the test sections, locations at which the distributor was forced to stop should be discarded. These involve about 25 feet on each side of the beginning

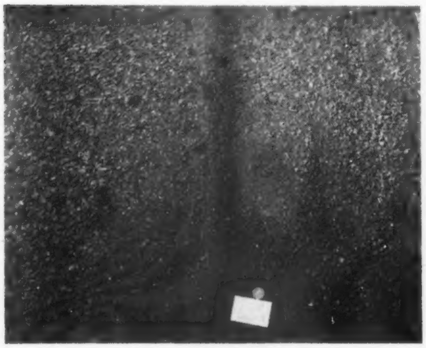


FIGURE 26—STONE.
SECTION 13—EAST SIDE—NORTH END. NO CURING BEFORE TRAFFIC. AFTER 3 DAYS OF TRAFFIC.

FIGURE 27—STONE.
SECTION 13—EAST SIDE—SOUTH END.
AFTER 4 DAYS OF TRAFFIC.

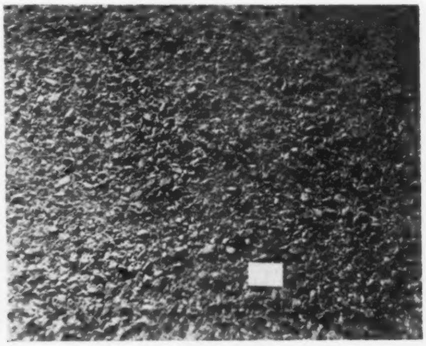


FIGURE 28—RECRUSHED STONE.
SECTION 14—WEST SIDE—NORTH END.
AFTER 2 DAYS OF TRAFFIC.

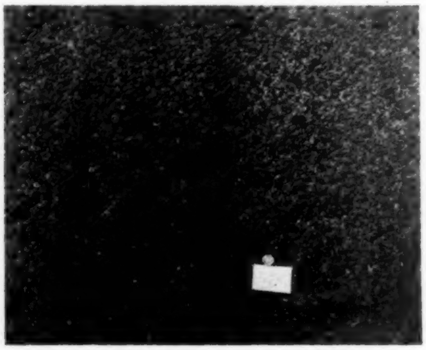


FIGURE 29—RECRUSHED STONE.
SECTION 14—EAST SIDE—SOUTH END.
AFTER 1 DAY OF TRAFFIC.

FIGURE 30.—RECRUSHED STONE.
SECTION 15. AFTER 1 DAY OF TRAFFIC.

and ending of a test section and at about the middle of Section 5 East, and either 5 or 9 West, and about the middle of Section 13 East.

This experiment was conducted in the highest spirit of cooperation on the part of everyone connected with the work. An earnest effort was made to build every section as nearly as possible according to the method prescribed and it is believed that a wide enough range in surface structure and surface texture has been obtained to make this study of value. The New York State Department of Public Works should be highly commended for its forward looking policy of practical research typified by this preliminary project, as a result of which ways of using available materials most economically and most satisfactorily will undoubtedly be developed.

SHORT DESCRIPTION OF SURFACE TREATMENT TEST SECTIONS

New York Route 9-W, September 18-25, 1942

Section 1. Single surface treatment. Apply 0.25 gal. of tar, cover with 25 lb. No. 1 stone. Roll.

Section 2. Single surface treatment. Apply 0.25 gal. of tar, cover with 30 lb. No. 1 tailings. Roll.

Section 3. Single surface treatment, Apply 0.25 gal. of tar, cover with 30 lb. No. 1 stone. Roll.

Section 4. Single surface treatment. Apply 0.25 gal. of tar, cover with 25 lb. No. 1 tailings. Roll.

Section 5. Single surface treatment. Apply 0.3 gal. of tar, cover with 40 lb. of stone composed of a mixture of 1/3 No. 2 and 2/3 No. 1. Roll.

Section 6. Ditto, with tailings.

Section 7. Double surface treatment. Apply 0.4 gal. of tar, cover with 50 lb. of stone composed of 1/3 No. 2 and 2/3 No. 1, roll, then apply 0.25 gal. of tar, cover with 25 lb. No. 1 stone, and again roll. Base course subjected to traffic for 2 or 3 days and swept before applying second course.

Section 8. Ditto, with tailings.

Section 9. Single surface treatment. First spread 20 lb. of No. 2 stone uniformly on the concrete base, then treat with 0.45 gal. of tar, then cover with 30 lb. of a mixture of 80 per cent No. 1 and 20 per cent No. 1A stone and finally roll.

FIGURE 31.
SECTION 15. SHOWS WHIP-OFF OF LOOSE STONE.

FIGURE 32.
GENERAL VIEW OF SECTION 15, LOOKING NORTH—EAST SIDE NEWLY COMPLETED. WEST SIDE AFTER 1 DAY OF TRAFFIC.

DATA ON EXPERIMENTAL BITUMINOUS SURFACE TREATMENTS

ON CONCRETE PAVEMENT NEW YORK STATE ROUTE 9-W, SOUTH OF ALBANY, N. Y., SEPTEMBER 18-25, 1942.

Test sections start at about 2.5 miles south of intersection of New York Routes 9-W and 32 (Bethlehem Center School or Glenmont P. O.) and end about 0.25 miles north

Section Number and Side of Road	Aggregate	Single or Double Surface Treatment	Theoretical Quantities of Materials in order of application (See Note 1)						Actual Quantities of Materials in order of application						Temperature °F.			Da La 19 Se
			1st		2nd		3rd		1st		2nd		3rd					
			Tar	Aggregate	Tar	Aggregate	Tar	Aggregate	Tar	Aggregate	Tar	Aggregate	Tar	Aggre-gate	Air	Aggre-gate	Tar	
1 West	Limestone	Single	0.25	25 (No. 1)	....	....	....	....	0.25	25.3	....	....	....	....	78	72	210	1
1 East	Limestone	Single	0.25	25 (No. 1)	....	....	....	....	0.25	21.4	....	....	....	....	78	72	210	1
2 West	Tailings	Single	0.25	30 (No. 1)	....	....	....	....	0.25	32.4	....	....	....	....	78	72	210	1
2 East	Tailings	Single	0.25	30 (No. 1)	....	....	....	....	0.25	30.5	....	....	....	....	78	72	210	1
3 West	Limestone	Single	0.25	30 (No. 1)	....	....	....	....	0.25	31.5	....	....	....	....	78	72	210	1
3 East	Limestone	Single	0.25	30 (No. 1)	....	....	....	....	0.25	34.7	....	....	....	....	78	72	210	1
4 West	Tailings	Single	0.25	25 (No. 1)	....	....	....	....	0.25	19.8	....	....	....	....	78	72	210	1
4 East	Tailings	Single	0.25	25 (No. 1)	....	....	....	....	0.25	22.3	....	....	....	....	78	72	210	1
5 West	Limestone	Single	0.3	40 (Mixture X)	....	....	....	....	0.3	42.8	....	....	....	....	70	72	195	1
5 East	Limestone	Single	0.3	40 (Mixture X)	....	....	....	....	0.3	35.2 (40.3 2nd test)	....	....	....	....	75	72	215	1
6 West	Tailings	Single	0.3	40 (Mixture X)	....		....	....	0.3	50.0	....	....	....	....	70	....	215	1
6 East	Tailings	Single	0.3	40 (Mixture X)	....	....	....	....	0.3	40.8	....	....	....	....	70	....	215	1
7 West	Limestone	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	....	....	0.4	47.2	0.25	25.0	....	....	B, 70 S, 68	....	....	B, S,
7 East	Limestone	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	....	....	0.4	40.0	0.25	22.7	....	....	B, 52 S, 62	....	....	B, S,
8 West	Tailings	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	....	....	0.4	52.5	0.25	30.0 (22.4 2nd test)	....	....	B, 70 S, 68	....	215	B, S,
8 East	Tailings	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	....	....	0.4	53.0	0.25	23.4	....	....	B, 55 S, 56	.... S, 58	....	B, S,
9 West	Limestone	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....	25.0	0.45	28.0	....	....	64	....	....	2
9 East	Limestone	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....	11.5	0.35	30.0 (36.7 last 200′)	....	....	72	....	220	2
10 West	Tailings	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....	21.0	0.45	32.5	....	....	64	....	....	2
10 East	Tailings	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....	22.7	0.45	35.3	....	....	62	....	....	2
11 West	Limestone	Double	....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)	....	20.0	0.35	26.5	0.15	9.3	60	....	....	2
11 East	Limestone	Double	....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)	....	a33.3 b28.5	0.35	18.9	0.15	7.0	65	....	....	2
12 West	Tailings	Double	....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)	....	24.4	0.35	22.0	0.15	15.0	60	....	230	2
12 East	Tailings	Double	....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)	....	17.0	0.35	21.5	0.15	10.2	69	....	....	2
13 West	Limestone	Double	0.25	25 (Mixture Y)	0.25	25 (Mixture Y)	....	....	0.25	25.1	0.25	25.0	....	....	56	58	225	2
13 East	Limestone	Double																
(South 500′)			0.25	25 (Mixture Y)	0.20	25 (Mixture Y)	....	....	0.25	26.0	0.20	25.1	....	....	56	....	....	
(North 500′)			0.25	25 (Mixture Y)	0.25	25 (Mixture Y)	....	....	0.25	26.0	0.25	25.1	....	....	56	....	....	B S,
14 West	Recrushed Limestone	Single	0.3	40 (Mixture X)	....	....	....	....	0.3	43.4	....	....	....	....	64	....	....	
14 East	Recrushed Limestone	Double																
South			0.25	40 (Mixture X)	0.15	15 (No. 1A)	....	....	0.25	40.8	0.15	15.0	....	....	64	....	....	
(North 374′)			0.25	30 (Mixture X)	0.15	15 (No. 1A)	....	....	0.25	28.2	0.15	16.0	....	....	49	....	225	
15 West	Recrushed Limestone	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....	17.2	0.45	35.0	....	....	65	63	220	
15 East	Recrushed Limestone																	
(South 550′)		Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....	17.2	0.45	35.0	....	....	65	....	....	
(North 200′)		Double	....	20 (No. 2)	0.35	30 (Mixture Y)	0.15	10 (No. 1)	....	20.0	0.35	30.0	0.15	10.0	66	....	....	

Note 1: Tar quantities are gallons per square yard. Aggregate quantities are pounds per square yard. Aggregate Size Numbers are New York Highway Designations:

Sieve Sizes	Percent Passing		
	No. 2	No. 1	No. 1A

B = base course. S = surface course.

Section 1 is farthest from Albany and Section 15 is nearest. The base course of Se
2 or 3 days then loose material was broomed off before applying the se

All sections, except 7 and 8, were completed the day they were started, that is, t
rolling the first course.

a = first 400 ft.

b = last 600 ft.

DATA ON EXPERIMENTAL B

ON CONCRETE PAVEMENT NEW YORK STATE ROU

Test sections start at about 2.5 miles south of intersection of New York Routes 9-W an

Section Number and Side of Road	Aggregate	Single or Double Surface Treatment	Theoretical Quantities of Materials in order of application (See Note 1)					
			1st		2nd		3rd	
			Tar	Aggregate	Tar	Aggregate	Tar	Aggregate
1 West	Limestone	Single	0.25	25 (No. 1)	.....	.....	.....	.....
1 East	Limestone	Single	0.25	25 (No. 1)	.....	.....	.....	.....
2 West	Tailings	Single	0.25	30 (No. 1)	.....	.....	.....	.....
2 East	Tailings	Single	0.25	30 (No. 1)	.....	.....	.....	.....
3 West	Limestone	Single	0.25	30 (No. 1)	.....	.....	.....	.....
3 East	Limestone	Single	0.25	30 (No. 1)	.....	.....	.....	.....
4 West	Tailings	Single	0.25	25 (No. 1)	.....	.....	.....	.....
4 East	Tailings	Single	0.25	25 (No. 1)	.....	.....	.....	.....
5 West	Limestone	Single	0.3	40 (Mixture X)	.....	.....	.....	.....
5 East	Limestone	Single	0.3	40 (Mixture X)	.....	.....		
6 West	Tailings	Single	0.3	40 (Mixture X)	.....	.....	.....	.....
6 East	Tailings	Single	0.3	40 (Mixture X)	.....	.....	.....	.....
7 West	Limestone	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	.....	.....
7 East	Limestone	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	.....	.....
8 West	Tailings	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	.....	.....
8 East	Tailings	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	.....	.....
9 West	Limestone	Single	.....	20 (No. 2)	0.45	30 (Mixture Y)	.....	.....
9 East	Limestone	Single	.....	20 (No. 2)	0.45	30 (Mixture Y)	.....	.....
10 West	Tailings	Single	.....	20 (No. 2)	0.45	30 (Mixture Y)	.....	.....
10 East	Tailings	Single	.....	20 (No. 2)	0.45	30 (Mixture Y)	.....	.....
11 West	Limestone	Double	.....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)
11 East	Limestone	Double	.....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)
12 West	Tailings	Double	.....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)
12 East	Tailings	Double	.....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)
13 West	Limestone	Double	0.25	25 (Mixture Y)	0.25	25 (Mixture Y)	.....	.....
13 East	Limestone	Double						
(South 500′)			0.25	25 (Mixture Y)	0.20	25 (Mixture Y)	.....	.....
(North 500′)			0.25	25 (Mixture Y)	0.25	25 (Mixture Y)	.....	.....
14 West	Recrushed Limestone	Single	0.3	40 (Mixture X)	.....	.....	.....	.....
14 East	Recrushed Limestone	Double						
South			0.25	40 (Mixture X)	0.15	15 (No. 1A)	.....	.....
(North 374′)			0.25	30 (Mixture X)	0.15	15 (No. 1A)	.....	.....
15 West	Recrushed Limestone	Single	.....	20 (No. 2)	0.45	30 (Mixture Y)	.....	.....
15 East	Recrushed Limestone							
(South 550′)		Single	.....	20 (No. 2)	0.45	30 (Mixture Y)	.....	.....
(North 200′)		Double	.....	20 (No. 2)	0.35	30 (Mixture Y)	0.15	10 (No. 1)

Note 1: Tar quantities are gallons per square yard. Aggregate quantities are pounds per square yard. Aggre
Size Numbers are New York Highway Designations:

Sieve Sizes	Percent Passing		
	No. 2	No. 1	No. 1A

L BITUMINOUS SURFACE TREATMENTS

ROUTE 9-W, SOUTH OF ALBANY, N. Y., SEPTEMBER 18-25, 1942.

V and 32 (Bethlehem Center School or Glenmont P. O.) and end about 0.25 miles north of intersection.

	Actual Quantities of Materials in order of application						Temperature °F.			Date Laid 1942 Sept.	Time of Laying	Number of Times Rolled		
	1st		2nd		3rd									
te	Tar	Aggregate	Tar	Aggregate	Tar	Aggre-gate	Air	Aggre-gate	Tar			1st	2nd	3rd
...	0.25	25.3	...	...	...	...	78	72	210	18	9:15am	10	...	...
...	0.25	21.4	...	...	...	...	78	72	210	18	...	2	...	...
...	0.25	32.4	...	...	...	...	78	72	210	18	...	4	...	...
...	0.25	30.5	...	...	...	...	78	72	210	18	...	4	...	...
...	0.25	31.5	...	...	...	...	78	72	210	18	...	1	...	...
...	0.25	34.7	...	...	...	...	78	72	210	18	...	1	...	...
...	0.25	19.8	...	...	...	...	78	72	210	18	...	1	...	...
...	0.25	22.3	...	...	...	...	78	72	210	18	...	1	...	...
...	0.3	42.8	...	...	...	...	70	72	195	19	8:40am	10	...	...
...	0.3	35.2 (40.3 2nd test)	...	...	...	...	75	72	215	19	3:20pm	10	...	...
...	0.3	50.0	...	...	...	...	70	...	215	19	11:30am	4	...	...
...	0.3	40.8	...	...	...	...	70	...	215	19	2:38pm	4	...	...
...	0.4	47.2	0.25	25.0	...	...	B, 70 S, 68	...	...	B, 19 S, 22	B, 9:50am S, 5:45pm	4-6	6	...
...	0.4	40.0	0.25	22.7			B, 52 S, 62	...	...	B, 21 S, 23	B, 9:15am S, 9:05am	4-6	6	...
...	0.4	52.5	0.25	30.0 (22.4 2nd test)	...	...	B, 70 S, 68	...	215	B, 19 S, 22	B, 12:15pm S, 6:50pm	4-6	6	...
...	0.4	53.0	0.25	23.4	...	...	B, 55 S, 56	... S, 58	...	B, 21 S, 23	B, 10:15am S, 8:25am	4-6	6	...
...	...	25.0	0.45	28.0	...	...	64	...	...	22	3:00pm	...	6	...
...	...	11.5	0.35	30.0 (36.7 last 200′)	...	...	72	...	220	21	3:05pm	...	5	...
...	...	21.0	0.45	32.5	...	...	64	...	...	23	4:45pm	...	6	...
...	...	22.7	0.45	35.3	...	...	62	...	...	23	10:00am	...	6	...
1A)	...	20.0	0.35	26.5	0.15	9.3	60	...	...	22	11:40am	...	1	4
1A)	...	a33.3 b28.5	0.35	18.9	0.15	7.0	65	...	...	21	2:50pm	...	1	4
1A)	...	24.4	0.35	22.0	0.15	15.0	60	...	230	24	6:00pm	...	3	2
1A)	...	17.0	0.35	21.5	0.15	10.2	69	...	...	23	12:05pm	...	2	2
...	0.25	25.1	0.25	25.0	...	...	56	58	225	22	10:15am	2	3	...
...	0.25	26.0	0.20	25.1	...	...	56	...	...	21	5:30pm	2	3	...
...	0.25	26.0	0.25	25.1	...	...	56	...	...	B, 21 S, 22	9:35am	2	3	...
...	0.3	43.4	...	...	...	...	64	...	...	23	6:00pm	6	...	...
...	0.25	40.8	0.15	15.0	...	...	64	...	...	24	10:45am	3	6	...
...	0.25	28.2	0.15	16.0	...	...	49	...	225	25	9:30am	6	10	...
...	...	17.2	0.45	35.0	...	...	65	63	220	24	8:30am	6	...	...
...	...	17.2	0.45	35.0	...	...	65	...	...	25	10:30am	...	10	...
1)	...	20.0	0.35	30.0	0.15	10.0	66	...	...	25	12:30pm	...	10	...

Aggregate

B = base course. S = surface course.

Section 1 is farthest from Albany and Section 15 is nearest. The base course of Sections 7 and 8 were open to traffic for 2 or 3 days then loose material was broomed off before applying the seal coat.

All sections, except 7 and 8, were completed the day they were started, that is, the seal was applied immediately after rolling the first course.

a = first 400 ft.

b = last 600 ft.

Number and Side of Road	Aggregate	Double Surface Treatment	1st		2nd		3rd		
			Tar	Aggregate	Tar	Aggregate	Tar	Aggregate	Tar
1 West	Limestone	Single	0.25	25 (No. 1)	....	....	....	....	0.25
1 East	Limestone	Single	0.25	25 (No. 1)	....	....	....	....	0.25
2 West	Tailings	Single	0.25	30 (No. 1)	....	....	....	....	0.25
2 East	Tailings	Single	0.25	30 (No. 1)	....	....	....	....	0.25
3 West	Limestone	Single	0.25	30 (No. 1)	....	....	....	....	0.25
3 East	Limestone	Single	0.25	30 (No. 1)	....	....	....	....	0.25
4 West	Tailings	Single	0.25	25 (No. 1)	....	....	....	....	0.25
4 East	Tailings	Single	0.25	25 (No. 1)	....	....	....	....	0.25
5 West	Limestone	Single	0.3	40 (Mixture X)	....	....	....	....	0.3
5 East	Limestone	Single	0.3	40 (Mixture X)	....	....	....	....	0.3
6 West	Tailings	Single	0.3	40 (Mixture X)	....	....	....	....	0.3
6 East	Tailings	Single	0.3	40 (Mixture X)	....	....	....	....	0.3
7 West	Limestone	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	....	....	0.4
7 East	Limestone	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	....	....	0.4
8 West	Tailings	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	....	....	0.4
8 East	Tailings	Double	0.4	50 (Mixture X)	0.25	25 (No. 1)	....	....	0.4
9 West	Limestone	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....
9 East	Limestone	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....
10 West	Tailings	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....
10 East	Tailings	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....
11 West	Limestone	Double	....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)	....
11 East	Limestone	Double	....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)	....
12 West	Tailings	Double	....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)	....
12 East	Tailings	Double	....	20 (No. 2)	0.35	20 (No. 1)	0.15	10 (No. 1A)	....
13 West	Limestone	Double	0.25	25 (Mixture Y)	0.25	25 (Mixture Y)	....	....	0.25
13 East	Limestone	Double							
(South 500′)			0.25	25 (Mixture Y)	0.20	25 (Mixture Y)	....	....	0.25
(North 500′)			0.25	25 (Mixture Y)	0.25	25 (Mixture Y)	....	....	0.25
14 West	Recrushed Limestone	Single	0.3	40 (Mixture X)	....	....	....	....	0.3
14 East	Recrushed Limestone	Double							
South			0.25	40 (Mixture X)	0.15	15 (No. 1A)	....	....	0.25
(North 374′)			0.25	30 (Mixture X)	0.15	15 (No. 1A)	....	....	0.25
15 West	Recrushed Limestone	Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....
15 East	Recrushed Limestone								
(South 550′)		Single	....	20 (No. 2)	0.45	30 (Mixture Y)	....	....	....
(North 200′)		Double	....	20 (No. 2)	0.35	30 (Mixture Y)	0.15	10 (No. 1)	....

Note 1: Tar quantities are gallons per square yard. Aggregate quantities are pounds per square yard. Aggregate Size Numbers are New York Highway Designations:

Sieve Sizes	Percent Passing		
	No. 2	No. 1	No. 1A
1⅞	100	....	....
1	90-100	100	....
½	0-15	90-100	100
¼	....	0-15	90-100
⅛	....	....	0-15

Tar controlled by distributor operator—no test made. Tar used: N. Y. State item 73a—grade B—AASHO Std. RT-8 (Float test at 32° F. = 80—120.)

Mixture X: consists of ⅓ No. 2 and ⅔ No. 1.

Mixture Y: consists of 4/5 No. 1 and ⅕ No. 1A.

1st		2nd		3rd		°F.			Laid 1942 Sept.	Time of Laying	Times Rolled		
Tar	Aggregate	Tar	Aggregate	Tar	Aggregate	Air	Aggregate	Tar			1st	2nd	3rd
0.25	25.3	.....	.....	.....	.....	78	72	210	18	9:15am	10	.....	.....
0.25	21.4	.....	.....	.....	.....	78	72	210	18	.....	2	.....	.....
0.25	32.4	.....	.....	.....	.....	78	72	210	18	.....	4	.....	.....
0.25	30.5	.....	.....	.....	.....	78	72	210	18	.....	4	.....	.....
0.25	31.5	.....	.....	.....	.....	78	72	210	18	.....	1	.....	.....
0.25	34.7	.....	.....	.....	.....	78	72	210	18	.....	1	.....	.....
0.25	19.8	.....	.....	.....	.....	78	72	210	18	.....	1	.....	.....
0.25	22.3	.....	.....	.....	.....	78	72	210	18	.....	1	.....	.....
0.3	42.8	.....	.....	.....	.....	70	72	195	19	8:40am	10	.....	.....
0.3	35.2 (40.3 2nd test)	.....	.....	.....	.....	75	72	215	19	3:20pm	10	.....	.....
0.3	50.0	.....	.....	.....	.....	70	.....	215	19	11:30am	4	.....	.....
0.3	40.8	.....	.....	.....	.....	70	.....	215	19	2:38pm	4	.....	.....
0.4	47.2	0.25	25.0	.....	.....	B, 70 S, 68	.....	.....	B, 19 S, 22	B, 9:50am S, 5:45pm	4-6	6	.....
0.4	40.0	0.25	22.7	.....	.....	B, 52 S, 62	.....	.....	B, 21 S, 23	B, 9:15am S, 9:05am	4-6	6	.....
0.4	52.5	0.25	30.0 (22.4 2nd test)	.....	.....	B, 70 S, 68	.....	215	B, 19 S, 22	B, 12:15pm S, 6:50pm	4-6	6	.....
0.4	53.0	0.25	23.4	.....	.....	B, 55 S, 56	S, 58	.....	B, 21 S, 23	B, 10:15am S, 8:25am	4-6	6	.....
.....	25.0	0.45	28.0	.....	.....	64	.....	.....	22	3:00pm	.....	6	.....
.....	11.5	0.35	30.0 (36.7 last 200′)	.....	.....	72	.....	220	21	3:05pm	.....	5	.....
.....	21.0	0.45	32.5	.....	.....	64	.....	.....	23	4:45pm	.....	6	.....
.....	22.7	0.45	35.3	.....	.....	62	.....	.....	23	10:00am	.....	6	.....
.....	20.0	0.35	26.5	0.15	9.3	60	.....	.....	22	11:40am	.....	1	4
.....	a33.3 b28.5	0.35	18.9	0.15	7.0	65	.....	.....	21	2:50pm	.....	1	4
.....	24.4	0.35	22.0	0.15	15.0	60	.....	230	24	6:00pm	.....	3	2
.....	17.0	0.35	21.5	0.15	10.2	69	.....	.....	23	12:05pm	.....	2	2
0.25	25.1	0.25	25.0	.....	.....	56	58	225	22	10:15am	2	3	.....
0.25	26.0	0.20	25.1	.....	.....	56	.....	.....	21	5:30pm	2	3	.....
0.25	26.0	0.25	25.1	.....	.....	56	.....	.....	B, 21 S, 22	9:35am	2	3	.....
0.3	43.4	.....	.....	.....	.....	64	.....	.....	23	6:00pm	6	.....	.....
0.25	40.8	0.15	15.0	.....	.....	64	.....	.....	24	10:45am	3	6	.....
0.25	28.2	0.15	16.0	.....	.....	49	.....	225	25	9:30am	6	10	.....
.....	17.2	0.45	35.0	.....	.....	65	63	220	24	8:30am	6	.....	.....
.....	17.2	0.45	35.0	.....	.....	65	.....	.....	25	10:30am	.....	10	.....
.....	20.0	0.35	30.0	0.15	10.0	66	.....	.....	25	12:30pm	.....	10	.....

gate

B = base course. S = surface course.

Section 1 is farthest from Albany and Section 15 is nearest. The base course of Sections 7 and 8 were open to traffic for 2 or 3 days then loose material was broomed off before applying the seal coat.

All sections, except 7 and 8, were completed the day they were started, that is, the seal was applied immediately after rolling the first course.

a = first 400 ft.

b = last 600 ft.

B—

Section 10. Ditto, with tailings.

Section 11. Double surface treatment. First spread 20 lb. of No. 2 stone on the base, then treat with 0.35 gal. of tar and then cover with 20 lb. of No. 1 stone, roll, then treat with 0.15 gal. tar and cover with 10 lb. of No. 1A stone and finally roll.

Section 12. Ditto, with tailings.

Section 13. Double surface treatment. Apply 0.25 gal. tar, then 25 lb. of 80 per cent No. 1 and 20 per cent No. 1A mixed, roll lightly; immediately apply 0.25 gal. tar, then 25 lb. of No. 1 and No. 1A mixed, roll.

Section W. 14. Single surface treatment. Apply 0.3 gal. of tar and cover with 40 lb. of recrushed or cubical stone composed of a mixture of 1/3 No. 2 and 2/3 No. 1, and roll.

Section E. 14. S. of x. Double surface treatment. Apply 0.25 gal. of tar, cover with 40 lb. of recrushed or cubical stone mixed with 1/3 No. 2 and 2/3 No. 1; then treat with 0.15 gal. tar and cover with 15 lb. of No. 1A recrushed or cubical stone and roll.

Section E. 14. N. of x. Double surface treatment. Apply 0.25 gal. of tar, cover with 30 lb. of recrushed or cubical stone, mixed 1/3 No. 2 and 2/3 No. 1; then treat with 0.15 gal. of tar; cover with 15 lb. of No. 1A recrushed or cubical stone and roll.

Section 15. Single surface treatment. First spread 20 lb. of No. 2 recrushed or cubical stone uniformly on the concrete base, then treat with 0.45 gal. of tar, then cover with 30 lb. of a mixture of 80 per cent No. 1 and 20 per cent No. 1A recrushed or cubical stone and finally roll. (Note: Same as Sec. 9 except that recrushed or cubical stone is used.)

Section E. 15. Last 200 feet. Double surface treatment. First spread 20 lb. of No. 2 recrushed or cubical stone; treat with 0.35 gal. of tar then 30 lb. of No. 1 and No. 1A cubical stone mixed, then cover with 0.15 gal. tar and 15 lb. of No. 1A recrushed or cubical stone, and roll.

REMARKS REGARDING THE SECTIONS IN THE TABLE.

Section 1 West: Definitely over-rolled.

Section 5 West: Trouble with distributor at about the center of section—maybe a fat spot will develop.

Section 7 West: Spreader does not work well with mixture of sizes. 15-minute delay of spreader at the middle of section.

Section 7 East: Base course very rough texture with No. 2 stone very prominent. Cover stone was very wet.

Section 8 East: Tar light at beginning. 20-minute delay before spreading last 100 feet.

Section 9 West: Last 20 feet of base were recrushed stone, close together.

Section 9 East: Last 200 feet increased quantity of No. 1 and No. 1A seemed to more nearly fill the voids in the No. 2.

Section 10 West: Last 200 feet in first course was a mixture of No. 1 and No. 2 tailings. Also tailings for the second course was largely No. 1A.

Section 10 East: No. 2 tailings had about 15 per cent No. 1 and No. 1A.

Section 11 West: Four additional rollings over entire surface on September 23.

Section 11 East: Four additional rollings over entire surface on September 23.

Section 12 West: Last 50 feet of No. 1 tailings very light. Third rolling of base made after applying more No. 1.

Section 13 East: (South) Finished at 6:30 p.m. Stone was still wet upon completion of this part of surface. Traffic turned on in about one hour.

Section 13 East: (North) Immediately opened to traffic upon completion.

Section 14 West: Traffic turned on after about one hour. Spot in front of school skinned off during first night. Rolling stopped at 6 passes because of crushing of stone.

Section 14 East: (South) Base stone wet below surface when seal was applied. Sprinkling rain.

Section 14 East: (North) Tar seal coat was streaky a'ong east side and at center.

Section 15 West: Tar did not fully cover first 10 feet of section.

Section 15 East: (South) Tar very light at first 5 feet,—streaks with no tar over two small areas.

Aluminum Dust Helpful in Silicosis Control[1]

By GLENN H. CUMMINGS
Staff Correspondent of The Wall Street Journal

• Quarry operators confronted with the silicosis problem should find real encouragement in the knowledge that recent investigations offer definite hope that a satisfactory method of silicosis control, through the use of aluminum dust, has been developed. Read the following article for the latest information on this important subject.

MEDICAL science believes it has at last found a remedy for silicosis, the deadly lung disease which attacks workers who inhale silica dust in mines, quarries and foundries.

For many years, doctors have been seeking a cure or preventive for this industrial ailment which cuts down the working life of its victims and often leads to tuberculosis. In such a normal year as 1937 some 110,000 industrial workers in the United States were reported to be suffering from silicosis, 4,000 to 5,000 of them seriously.

The hazard from silica dust-laden air is greatest in such industries as anthracite mining, quarrying, drilling and tunneling in granite, ganister and sandstone, smelting and refining, foundries, potteries, glass works and stone products.

Aluminum Powder Used

The new weapon of medical men fighting the silica dust disease, curiously enough, is a fine aluminum powder. Sufferers from the disease merely inhale the harmless powder; the aluminum particles do the rest. Experiments have proved that more than half the victims treated in this way showed positive improvement while the progress of the disease was apparently arrested in the others. As a preventive for silicosis, workers inhale the powder before going to work.

This treatment is based on the theory that silica dust inhaled into the lungs is slowly transformed into harmful silicic acid by body fluids; normal lung tissue is replaced by scar tissue and the lungs can no longer breathe deeply. Doctors found that the aluminum particles, once inhaled, form a protective coating over the silica dust, prevent it from dissolving.

The chain of events that led to aluminum dust discovery actually dates back to 1926 when victims of silicosis became eligible for benefits under the Ontario Workmen's Compensation Act. Mine operators and doctors were suddenly made aware of its significance to the Canadian mining industry.

Working conditions were quickly improved to eliminate as much silica dust as possible from the air, but mining men realized they were confronted by a problem which, if it were to be fully solved, demanded time and money.

Mine Company Backs Research

Almost entirely responsible for the progress in combatting the disease is McIntyre-Porcupine Mines, Ltd., at Schumacher, Ontario, in the heart of Canada's great porcupine gold mining area. On the recommendation of the late Sir Frederick Banting, one of the discovers of insulin, this mining company in 1932 called in Drs. J. J. Denny, W. D. Robson and D. A. Irwin to experiment with silicosis.

For four years these men worked with many substances without success; then, in 1936, Drs. Denny and Robson discovered that small amounts of the aluminum powder reacted favorably on inhaled silica dust. Until 1939 they experimented with animals, then turned their attention to human silicosis.

A clinic known as the Porcupine Clinic for Silicosis Research was established at St. Mary's Hospital, Timmins, Ontario, under the direction of Dr. D. W. Crombie, medical superintendent of Ontario's Queen Alexandra Sanatorium and outstanding chest authority. He was assisted by Dr. J. L. Blaisdell, pathologist, and Miss G. MacPherson, chemist.

Other mines in the porcupine gold area joined McIntyre-Porcupine in supplying funds to support the new clinic which has been in operation since 1939. Total cost of the project has been $75,000.

Aluminum Company Helps

The clinic doctors went to Dr. Francis C. Frary, the Aluminum Co. of America's research director, to assure themselves that aluminum powder

[1] Reprinted from the June 24, 1944, issue of *The Wall Street Journal*.

would be as harmless to humans as it had proved to animals. He made available to them the health records of 125 employes who for many years had been engaged in the manufacture of finely powdered metallic aluminum for the paint and ink industries; their health records seemed even better than those of the plant's 3,000 other workers.

Thirty-four silicotics were chosen for the experiments; of these 18 showed little or no disability. All except one of them continued to be exposed to silica dust throughout the test period. Workers were given from 200 to 300 treatments, inhaling the aluminum powder for half an hour six days a week.

Of those treated, 56 per cent showed improvement, apparent chiefly in the lessening or disappearance of shortness of breath, cough, pain in the chest and fatigue. A reduction in the number of colds and a gain in weight also has been observed in many of the patients.

In all the other workers the progress of the disease was apparently arrested; this group of patients held its own in spite of continuous employment in silica dust during the treatment.

Untreated Sufferers Get Worse

For purposes of comparison, doctors simultaneously watched the health of a "control group" of silicotics who were not given the aluminum powder treatments. Of these, 65 per cent were in poorer condition at the end of the test period.

While the Ontario researchers were carrying on their experiments. Dr. J. W. G. Hannon of Washington, Pa., obtained permission from them to use the aluminum treatment with men in the ceramics, silica-brick, foundry, steel and glass industries in that state.

His first test group of 33 workers treated with aluminum powder showed improvement in all cases, gain in weight, better lung ventilation and increased ability to work.

Another group of 143 workers, whose silcotic disability was confirmed by X-ray findings, finished the treatment period with 135 improvements, six unimproved and two worse.

Dr. Hannon's Findings

Dr. Hannon summarizes his findings as follows:

1. Inhalation of aluminum powder will alleviate the symptoms of silicosis in a high percentage of cases.
2. Treatment with aluminum results in improved health, morale, home conditions, industrial labor relations and production capacity.
3. The rapid type of silicosis is particularly responsive to aluminum therapy.
4. Inhalation of aluminum powder will prevent silicosis.

The aluminum treatment for silicosis has been patented in most of the principal countries of the world by McIntyre Research, Ltd., organized by Drs. Denny and Robson and the McIntyre-Porcupine Mines. They have offered free use of the patents to the world, stipulating only that a license fee be charged to cover the cost of administration and in due course provide sufficient revenue to continue research on silicosis and other similar diseases.

One reason for patenting the treatment, according to McIntyre Research officials, is to prevent careless and incompetent researchers from using aluminum dust under improper conditions and perhaps obtaining unsatisfactory results and unfavorable publicity.

All workers at McIntyre-Porcupine Mines now must take preventive aluminum treatments while they change their clothes before entering the mine. The air in their "change room" is permeated with aluminum powder and as each man takes an average of ten minutes to change into his working clothes, his daily treatment lasts that long.

Silicosis is slow to develop, usually taking seven years or more for initial symptoms to appear. Some cases, however, have developed in as short a period as three years. Its incidence is particularly great in workers exposed for 20 years or more. Much depends upon the amount of dust in the air and upon the physical condition of the worker.

A study made in 1939 of workers in three representative lead-copper and lead-silver underground mines in Utah showed that of 385 men (drillers, miners and muckers) employed principally at the face of the mines where dust conditions were worst, 24.4 percent of those who had worked six years had contracted the disease, 41.1 percent who had worked 13 years had it and 68.2 percent who had worked 20 years were suffering from its effects.

Most states include silicosis among the industrial hazards covered by workmen's compensation insurance. Committees of the Second National Silicosis Conference held in Washington in 1937 unanimously recommended that all states take similar action.

Some Field Observations on Industry Conditions

By E. W. BAUMAN
Field Engineer
National Crushed Stone Association

AS FIELD ENGINEER of the National Crushed Stone Association, I have had occasion during recent months to visit, engineers, contractors, stone producers, and officials in various capacities connected with the construction industry in the following states: New York, Pennsylvania, Massachusetts, Connecticut, Illinois, Virginia, North Carolina, South Carolina, Tennessee, Arkansas, Texas, Oklahoma, Missouri, and Kentucky.

In discussions with member companies concerning their problems I have been impressed by their interest in and knowledge of plans and specifications which apply to construction projects involving the use of crushed stone products. Not only does this interest apply to details of construction, but also to the performance of the finished structure in field service. Recognition of the need for more complete information as to field performance has stimulated in many instances the conducting of field condition surveys on existing structures, some of which have been undertaken by producing interests alone and others carried out cooperatively with engineers and highway officials. I have participated in some of the inspections of existing structures and in a number of instances have reviewed reports of the completed surveys.

The fact that aggregates play an important part in the quality and durability of resultant concrete is axiomatic among concrete technicians. With respect, however, to concrete pavement slabs, the results of these inspections and surveys indicate that aggregates, and especially the coarse aggregate, influence to a greater degree the durability of concrete when placed in service as comparatively thin slabs, than is the case when used in structures such as abutments, footings, dams, or other types of mass construction. In practically all cases observed, the pavements placed with good quality aggregate in the concrete are outstanding in performance, based on low maintenance costs and a high rating for life expectancy, as contrasted to those sections where coarse aggregates of questionable quality were used. Inferior aggregates are characterized by their high coefficient of expansion, high absorption, relatively low resistance to the effect of freezing and thawing, and by the low transverse strengths they impart to concrete.

While, in general, laboratory tests have been developed to determine the suitability of aggregates for use in certain classes of construction, the results of such tests are not always borne out in actual field service and the true facts must be obtained by observing the behavior under field conditions. Also, sometimes the results of recognized laboratory tests are negative for aggregates that are known to give satisfactory results in field service, and for that reason some specifications carry a qualifying clause such as the one noted in "Standard Specifications for Coarse Aggregates for Concrete (A.A.S.H.O. Designation M80-42)." It would seem that if satisfactory service performance may be used as a reliable index for the suitability of an aggregate not meeting preliminary laboratory tests, then even more so should results of field service be used to eliminate those materials not giving satisfactory performance, notwithstanding a clean bill of health assigned them by preliminary tests. A paper presented at the 1944 Purdue Road School by Tilton E. Shelburne, Research Engineer for the Joint Highway Research Project, Purdue University, on "The Value of Pavement Performance Surveys," elaborates more in detail on this subject, and for those interested in this problem a study and review of this paper is recommended. In my discussions of results obtained from field inspections and surveys with some of the engineers and public officials working on the post-war highway program, it appears that the relative suitability of aggregates for concrete pavement will be given even greater consideration than has been the practice in the past.

With regard to the post-war highway program, notwithstanding the handicap under which most highway departments are working due to reduced personnel, many of them are making real progress in preparing a schedule of projects. These will be available for early release to contract as soon as construction activities can again be resumed. While Congress has not yet passed legislation providing Federal-aid for highway construction for the post-war period, the feeling prevails that some form of legislation will be adopted to provide the necessary

funds. An interesting account of our highway needs was presented to the House Roads Committee this spring by leading officials of the various highway departments as testimony for use by the Committee in considering highway legislation. Pertinent information carried in this testimony is briefed in the April 1944 issue of "American Highways," official organ of the American Association of State Highway Officials.

A type of road surfacing used on appreciable mileage and giving good results in the Carolinas along the coastal section, is their so-called sand-asphalt mixture. This is a hot plant mix utilizing local sand with about 6 per cent of 85 to 100 penetration asphalt in the base mixture and from 7 to 10 per cent asphalt of the same penetration in the surface mixture. A typical cross-section for this type of construction usually calls for a 3 in. base with a 2 in. surface. The cost of this surfacing by contract was well under $1.00 per sq. yd. under pre-war conditions, with an average price running between 85 and 90 cents per sq. yd. Even though this sand-asphalt mixture without the addition of crushed aggregate is apparently giving good results, in all probability the use of stone chips would improve the quality of the mixture enough to fully justify the cost of shipping in the coarse aggregate. Savings resulting from a lower bitumen content, a somewhat thinner section, lower maintenance costs, and longer service life, should offset the higher cost involved in the original construction. Mention is made of this situation primarily for the purpose of illustrating a point in highway economics in which I often find myself involved when discussing, with design engineers, construction costs as related to highway service. For the investigation of this idea I would like to see a research project constructed under the supervision of the state highway department, half of the project surfaced with sand-asphalt and the other half with stone-filled sand-asphalt. Proper amounts of stone chips and optimum percentages of asphalt to be used in the mixture should be determined in the laboratory based on factors of stability, workability, and economy.

It is interesting to note the increased activity that limestone producers are manifesting to meet the increased demand of the Agricultural Adjustment Administration. This agency has tentatively established requirements for the 1944 Agricultural Conservation Program of approximately 15,000,000 tons of agricultural limestone, representing an increase over last year's production of almost 50 per cent. While many small producers have set up plants to help supply this demand, usually of 200 to 300 tons daily capacity, the bulk of the tonnage is being furnished by plants of established stone producers who have in many instances expanded their facilities to materially increase production of this product. One of our member companies in the middle west has recently completed the installation of equipment for producing agricultural limestone so that they now have a daily capacity of over 4,000 tons. Another of our member companies has set up a new plant in one of the southern states which will increase the tonnage produced in that state by many times the total present output. Even though we can hardly expect the present market level to be maintained, evidently those producers close to the soil conservation program feel justified in making the investment for increased producing facilities, in the belief that there will still be a good market for this product after the war.

The center striping of highways economically and effectively has always been troublesome to highway engineers, and under the present situation of material and labor shortages it is even more of a problem than before. The State of Texas is solving this difficulty, in part at least, by the use of a black center-line stripe formed with "bituminous center-line cutback" and trap rock chips. I rode over many miles of bituminous as well as concrete pavements on which this type of center-line had been applied and it is surprising how effectively this stripe actually divides the pavement lanes, both in daytime and at night. When properly applied, long service is claimed with comparatively low initial cost of application. Anyone interested in the method of application and specification for this material can obtain information by writing to the Maintenance Division of the Texas Highway Department.

After visiting some of the quarries and plants of our member companies in recent months and discussing with management the many problems they have had to solve in establishing during the war period an all-time tonnage record for the industry, I feel impelled to make some mention of this achievement. The fact that no applications for Army or Navy E awards were made by crushed stone producing plants as such, should not be construed to mean that the product furnished was not essential to the war effort. In general, those responsible for acquiring the much needed materials for war and essential civilian requirements classify these materials either as critical or essential, and priority ratings for obtaining the necessary supplies required in the production thereof are issued by the War Production Board. Under Preference Rating Order P-56, ad-

(Continued on page 26)

Gravel and Stone in Comparable Mixes[1]

By W. S. ELLIOTT

Chief, Materials Section, Department of Public Works, City of New York

DOLOMITIC LIMESTONE and quartz gravel are representative of coarse aggregates economically available to the City of New York. As a result of discussions of the relative compressive strengths obtainable from concrete made with these two materials under comparable conditions, it was decided to conduct a series of laboratory tests. The tests were sponsored by the Department of Public Works of New York City, assisted by engineers of the office of the President of the Borough of Queens. They were conducted in cooperation with the National Crushed Stone Association and the National Sand and Gravel Association.

Two series of tests were made involving the manufacture and testing in compression of 216 standard 6x12-in. concrete cylinders. Test specimens were made for each of the two coarse aggregates containing 4, 5, 6 and 7 bags of cement per cu. yd. The aim was to maintain the consistency of the concrete to that represented by a standard slump of 4 to 5 inches.

The proportions of fine to coarse aggregates were calculated in accordance with the procedure outlined in Bulletin 11 of the National Crushed Stone Association, "A Method for Proportioning Concrete for Compressive Strength, Durability and Workability," by A. T. Goldbeck and J. E. Gray. The method provides for the use of a constant volume of dry-rodded coarse aggregate per unit of volume of concrete, irrespective of the cement content or of the type of coarse aggregate. The quantity of coarse aggregate depends upon its maximum size and upon the grading of the fine aggregate. Proportions calculated by this procedure were checked by other methods by Stanton Walker, director of engineering of the National Sand and Gravel Association and agreed to by him. Source of aggregates and data on physical characteristics of both the fine and coarse aggregates are given in Table 1. Coarse aggregates were separated into different sizes and recombined to approximately the same gradings.

Test Procedure

It was desired to make the tests with a cement that might give reasonably conservative values. With that purpose in mind a Type II portland cement was used in Series I. The sand made available for the Series I tests was quite finely graded as may be seen from Table 1. It was felt that the results obtained with the Type II cement might not be entirely typical of concrete used in building construction and, therefore, a Type I cement and a coarser sand were used for a second series of tests.

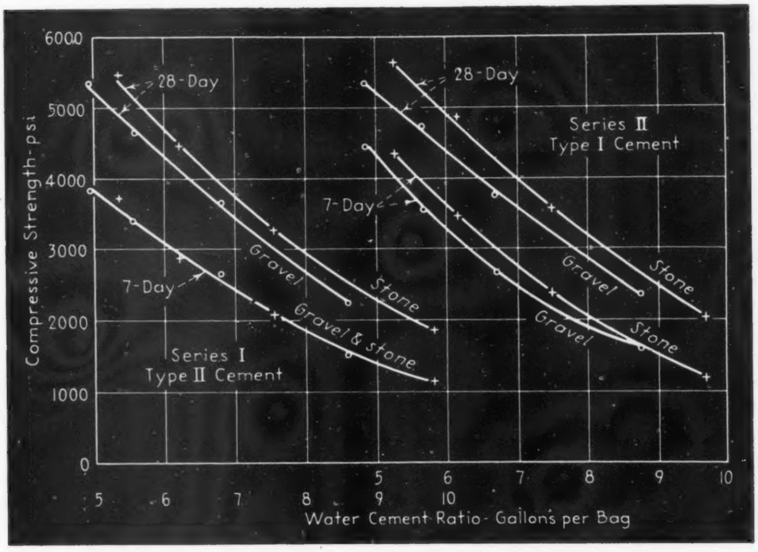
In each series, specimens were molded for the four different cement contents (4, 5, 6 and 7 bags per cu. yd. of concrete) on one day and the work repeated on two succeeding days. In Series I, five specimens were made from each batch, two of which were tested at 7 days and three at 28 days, making either six or nine specimens available for each condition of test. In Series II, four specimens were made from each batch, two being tested at 7 days and two at 28 days, resulting in six specimens for each condition of test.

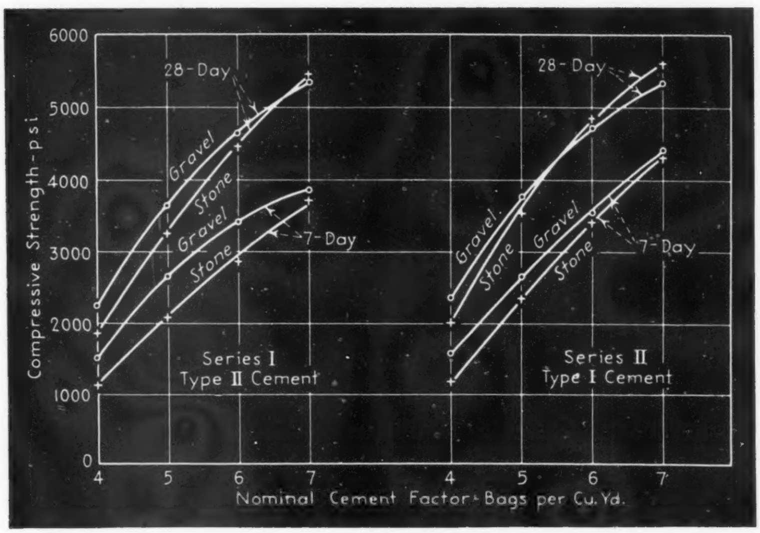
All aggregates were in approximately a saturated-surface-dry condition when incorporated in the concrete, which was mixed by hand with shovels in a water-tight pan. In Series I the batches were about 1.20 cu. ft. and in Series II about 0.9 cu. ft. The sand and cement were mixed first; the coarse aggregate was then added and all solid ingredients thoroughly mixed. Most of the estimated mixing water was then added and the concrete mixed; mixing was continued and the remainder of the mixing water added gradually until judgment indicated that the desired slump of 4 to 5 in. had been attained.

The cylinders were molded, by standard A. S. T. M. procedure, in 6x12 in. paraffin coated cardboard cylinder molds. After 24 hr. the cardboard forms were removed and the concrete cylinders stored in a moist room maintained at approximately 70 F. until tested. The cylinders of Series I and the 7-day cylinders of Series II were capped, top and bottom, with a sulphur compound. Difficulties with warped caps resulted and all remaining cylinders were capped with high-early-strength neat cement paste.

All specimens for Series I and the 7-day specimens for Series II were tested in one of two lever-type screw testing machines. With minor exceptions, those specimens requiring a total load of less than 100,000 lb. were tested in the 100,000-lb. capacity testing machine of the Borough of Queens. The stronger specimens (total load over 100,000 lb.) were tested in the 400,000-lb. capacity testing machine of the Borough of Queens. Erratic results were obtained on the 400,000-lb. machine as a result of which the 28-day specimens of Series II were tested in the

[1] Reprinted from February 10, 1944 issue of "Engineering News-Record".





COMPARABLE STRENGTHS OF STONE AND GRAVEL CONCRETE. FIG. 1 (TOP) SHOWS RELATION OF WATER-CEMENT RATIO TO STRENGTH OF CONCRETE MADE WITH EACH MATERIAL. FIG. 2 (BELOW) SHOWS STRENGTH WITH SAME CEMENT FACTOR. CURVES ARE PLOTTED ON THE BASIS OF THE ADJUSTED AVERAGES OF TEST SPECIMENS SHOWN IN TABLE 2.

200,000-lb. capacity hydraulic testing machine of the Borough of Bronx.

Test Results

Tables 2 and 3 summarize the results of the concrete tests. Table 2 shows the strengths of each cylinder. It will be observed that two averages are shown—an "average" and an "adjusted average." The "adjusted average" represents an endeavor to minimize the effects of erratic results referred to previously. It consists of the averages of the highest testing two-thirds of the specimens in each group; that is, the lowest testing one-third of the specimens in each group were discarded. This procedure was followed, instead of more commonly applied rules for discarding erratic results, because it was felt that the particular errors of testing encountered in this work would practically always lead to results too low and practically never to results too high. In any event, all groups of specimens were treated alike in securing the adjusted average. Table 3 shows average values for compressive strength, cement factor, water-ratio, slump, weight of concrete per cu. ft., and quantities required per cu. yd.

Fig. 1 shows water-ratio strength relations for the two Series. Except for the 7-day tests of Series I, the water-ratio strength curve for the crushed stone concrete is somewhat higher than for the gravel concrete. It is worthy of note that the differences between the two curves are greater in Series II than in Series I. A principal difference between these two series, it will be recalled, was that Type II cement and a finely graded sand were used in Series I, while Type I cement and a more coarsely graded sand were used in Series II. Also there were the differences in capping and testing procedure referred to earlier.

Fig. 2 summarizes the cement content strength relations found. Here again the effect of some differences in materials or procedure as between Series I and II is evidenced. In Series I the gravel concrete was generally higher in strength, for a given cement content, than the stone concrete—these differences being most evident in the leaner mixes and practically disappearing in the 7-sack mixes. In Series II, the gravel concrete strengths were somewhat higher than the stone concrete strengths for the 7-day tests and for the 4 and 5-bag mixes of the 28-day tests. The 6 and 7-bag concrete, in the 28-

day tests, showed somewhat higher strengths for the stone concrete than for the gravel concrete.

Further Study Needed

These data are presented as a matter of general interest and as of particular interest to engineers and producers in New York City. It should be emphasized that there is no thought in the mind of the author that they are indicative of results to be obtained with all gravels and all crushed stones or with different combinations of these materials. They are represented to show no more than what was obtained for the conditions of these tests.

The apparent effect of type of cement, grading of sand, and some other factor in these tests on the comparative results deserves further investigation.

COMMENT ON TESTS

By A. T. Goldbeck
Engineering Director,
National Crushed Stone Association

BULLETIN NO. 11 of the National Crushed Stone Association, "A Method for Proportioning Concrete for Compressive Strength, Durability and Workability" (For a short article on the method see *ENR* Nov. 5, 1942, p. 638), is based on tests which indicated that "different coarse aggregates of the same size will produce only immaterial variation in strength when the same cement factor and consistency are used." The present tests were really made to determine the validity of that statement as applied to New York aggregates.

Concrete as placed in construction is subject to many variables not present in laboratory concrete; hence, it is always advisable to assume that relatively low strength values may be obtained on the job, lower than would be obtained under ideal laboratory conditions. For design purposes, therefore, relatively conservative strength values for given cement factors should be assumed as has been done in Table II of Bulletin 11.

Apparently the method of design using the same cement factor and the same slump irrespective of the coarse aggregate gives safe results as applied to New York aggregates.

It will be interesting to compare the differences in strengths between the stone and gravel—first, using the same water-cement ratio, and second, using the same cement factor. This comparison is shown in Table 5. Column 4 shows the additional strength of stone over gravel concrete when both have the

TABLE 1.
PHYSICAL CHARACTERISTICS OF AGGREGATES

Crushed stone is dolomitic limestone from Tomkins Cove Quarry of the New York Trap Rock Corporation.
Gravel is quartz gravel from Oyster Bay, Long Island, N. Y., produced by Gallagher Bros. Sand and Gravel Corp.
Sand for Series I from Port Washington Plant of Metropolitan Sand and Gravel Corporation and for Series II from Oyster Bay, produced by Gallagher Bros. Sand and Gravel Corp.

Item	Physical Characteristics Series I			Series II		
	Stone	Gravel	Sand	Stone	Gravel	Sand
Sieve Analysis, percents retained on						
No. 100	----	----	96	----	----	97
No. 50	----	----	81	----	----	83
No. 30	----	----	38	----	----	45
No. 16	----	----	18	----	----	25
No. 8	----	----	7	100	100	12
No. 4	100	97	1	97	97	5
⅜ in.	75	75	----	75	75	0
½ in.	----	----	----	67	----	----
¾ in.	27	27	----	30	30	----
1 in.	0	0	----	0	0	----
Fineness Modulus	7.02	6.99	2.41	7.02	7.02	2.67
Miscellaneous Characteristics						
Specific Gravity (Bulk)	2.81	2.63	2.63	2.81	2.61	2.63
Absorption (24-hr.)	0.5	0.6	0.5	0.5	0.5	0.4
Wt. per cu. ft. lb.						
Solid	175.3	164.1	164.1	175.3	162.9	164.1
Dry-rodded	104.0	107.7	103.8	106.6	108.8	----

TABLE 2
DATA FROM STRENGTH TESTS

Summary of test results of individual cylinders. Adjusted average is average of the highest two-thirds of results in each group. Complete tabulation of breaking strengths of individual cylinders is shown for a 6-bag batch as typical.

Cement bags per cu. yd. of concrete (Nominal)		Compressive Strenth, p.s.i.							
		Series I				Series II			
		Stone		Gravel		Stone		Gravel	
		7d.	28d.	7d.	28d.	7d.	28d.	7d.	28d.
4	Average	1094	1762	1470	2143	1158	2004	1539	2322
	Adjusted Av.	1115	1846	1505	2217	1202	2018	1600	2357
5	Average	2029	3144	2574	3333	2307	3533	2625	3706
	Adjusted Av.	2068	3246	2630	3643	2371	3588	2656	3763
		2716	3976	3437	3580	3281	4399	3701	3926
		2805	4261	3531	4358	2895	4910	2984	4499
		----	3860	----	4316	----	----	----	----
		2927	3805	2936	4693	3400	4951	3380	4936
		2402	4586	2684	4162	3600	4696	3500	4735
		----	4719	----	4821	----	----	----	----
		2964	4393	3674	4679	3465	4823	3722	4569
		2790	4479	2895	4590	3405	4774	3099	4640
		----	4424	----	4684	----	----	----	----
6	Average	2767	4258	3193	4431	3341	4759	3398	4551
	Adjusted Av.	2872	4477	3394	4638	3468	4864	3576	4720
7	Average	3651	5231	3584	4904	4251	5430	4171	5229
	Adjusted Av.	3701	5469	3836	5354	4345	5646	4424	5358

TABLE 3
SUMMARY OF CONCRETE DATA

Each value is average of data for the three rounds of test specimens. Note that the strength values are the *adjusted averages* referred to in Table 2.

Cement bags per cu. yd. of Concrete Nominal	Measured	Pounds of Dry Aggregate per cu. yd. of Concrete Sand	Coarse Aggregate	Weight of Concrete lb. per cu. ft.	Slump in.	Water gal. per sack	Adjusted Average Compressive Strength, psi. 7d.	28d.
				Series I—Stone				
4	3.95	1375	2005	150.9	3¾	9.82	1115	1846
5	4.98	1315	2010	152.4	4¾	7.54	2068	3246
6	5.96	1255	2010	153.2	4¼	6.20	2872	4477
7	6.91	1185	2010	153.9	4¾	5.35	3701	5469
				Series I—Gravel				
4	3.93	1250	2060	147.2	3½	8.60	1505	2217
5	4.98	1180	2080	148.8	4½	6.81	2630	3643
6	5.95	1115	2080	149.5	4½	5.57	3394	4638
7	6.96	1040	2090	150.9	5	4.96	3836	5354
				Series II—Stone				
4	3.96	1395	1975	150.5	3½	9.68	1202	2018
5	4.95	1340	1970	151.0	5	7.50	2371	3588
6	5.96	1260	1980	152.1	4	6.15	3468	4864
7	6.97	1195	1985	153.3	4½	5.27	4345	5646
				Series II—Gravel				
4	3.97	1290	2020	147.3	4¼	8.77	1600	2357
5	4.96	1245	2020	148.4	4¼	6.70	2656	3763
6	5.97	1155	2030	148.9	4¾	5.67	3576	4720
7	6.93	1075	2020	149.1	4½	4.85	4423	5358

TABLE 4.

COMPARISON OF THE STRENGTHS REQUIRED FOR DESIGN PURPOSES INTERPOLATED FROM BULLETIN 11 OF THE N.C.S.A. AND THE ACTUAL 28-DAY LABORATORY TEST RESULTS.

Nominal Cement Factor	Strengths Required for Design Purposes (See NCSA Bulletin 11)	28-Day Strengths Series I Type II Cement Gravel	28-Day Strengths Series I Type II Cement Stone	28-Day Strengths Series II Type I Cement Gravel	28-Day Strengths Series II Type I Cement Stone
(A)	(B)	(C)	(D)	(E)	(F)
4	1400	2217	1846	2357	2018
5	2600	3643	3246	3763	3588
6	3700	4638	4477	4720	4864
7	4600	5354	5469	5358	5646

same water-cement ratio, and Column 7 shows how much stone is penalized in cement factor when the same W/C is used for stone and gravel mixes.

When values in Column 9 are compared with Column 4 it is seen that the differences in strength between the stone and gravel concretes, in the majority of cases, were less when both had the same cement factor than when both had the same water-cement ratio.

Concretes made with these respective coarse aggregates for practical purposes will have the same compressive strength when they have the same cement factor.

TABLE 5

COMPARISON OF DIFFERENCE IN STRENGTHS BETWEEN STONE AND GRAVEL FOR THE SAME WATER CEMENT RATIO AND FOR THE SAME CEMENT FACTOR.

1 W/C ratio Gal. per Sack	2 Compressive Strength, 28-day for Same W/C Gravel	3 Compressive Strength, 28-day for Same W/C Stone	4 Difference (3)—(2)	5 Cement Factor Gravel	6 Cement Factor Stone	7 Difference (6)—(5)	8 and 9 Difference in Strength for Same Cement Factor	
Series I—Type II Cement								
5	5300	5800	+500	6.95	7.5	.55	7 Sacks	+115*
6	4300	4700	+400	5.6	6.2	.6	6 "	−161
7	3450	3750	+300	4.85	5.35	.5	5 "	−400
8	2700	2950	+250	4.3	4.75	.45	4 "	−371
9	2000	2300	+300	3.85	4.10	.25		
Series II—Type I Cement								
5	5200	5900	+700	6.75	7.45	.70	7 Sacks	+288†
6	4400	4900	+500	5.6	6.1	.50	6 "	+144
7	3600	4000	+400	4.85	5.30	.45	5 "	−175
8	2900	3250	+350	4.35	4.75	.40	4 "	−339
9	2200	2500	+300	3.9	4.25	.35		

+ indicates stone exceeds gravel.
* Values are differences between Col. C and D of Table 4.
† Differences, Cols. E and F.

Safe Practices in Quarries[1]

By JOHN O'CALLAGHAN[2]
Superintendent of Lone Star Cement Corporation, Birmingham, Ala.

SAFE practices as applied to cement quarries is a subject that covers a considerable amount of territory, and not all hazards, both mental and physical, that exist in the average cement plant quarry, can be covered in a short space of time. This paper, therefore, will point out and treat only those hazards that have been stressed as especially dangerous and especially controversial by such organizations as the Portland Cement Association, the National Safety Council, Alabama state laws regarding "Safety in Open Pits and Quarries" and the speaker's personal experience.

Most of you are aware that the P. C. A. sent a questionnaire containing 143 questions to member companies in February 1943. There were 83 replies to this questionnaire, and from the answers the P. C. A. was able to make a comparison of the quarry practices of the various plants. As you might surmise, the answers were varied and far from being uniform. From the comparison made, the P. C. A. Subcommittee on Quarry Practice called attention in its annual report, to certain practices which it considered worth scrutinizing.

1. Foremost among these is the arrangement of having a safety engineer spend either part or full time at the quarry in cases where the quarry is not close to the mill site. We are assuming that a "safety engineer" is either a graduate engineer or a man with considerable experience in safety organization and practice. The word "engineer" has been loosely applied to many men during the past ten years and not all plants would agree as to just what constitutes a safety engineer.

We personally believe that the majority of plants cannot support a full time safety engineer, regardless of whether or not they believe in such an idea. If a safety engineer were available, he should most certainly be instructed to spend a considerable portion of his time in the quarry because, just as cement making starts in the quarry, so should safety start there. We believe that most mills use their superintendent and quarry foreman as substitutes and as "pinch hitters" for safety engineers and most of the burden falls on the foreman with the superintendent acting in an advisory and periodic observing capacity. I say "periodic observing" because the writer makes a practice of observing quarry operations and discussing unsafe practices and hazards observed, with the foreman. Between the two men, a speedy decision can be made regarding rules, practices and the purchase of safety equipment if deemed necessary.

2. The question of a separate safety committee for the quarry is next brought up.

Over half of the 83 plants questioned stated that the plant safety committee took care of the quarry, though 11 mills did have a safety committee functioning in the quarry. We believe that it is imperative that the quarry have their own safety organization, because after all the quarry has special everyday problems that casual inspections and discussions from men in other departments will not detect or cure.

The practice at our plant is to have weekly safety meetings in the quarry for quarry personnel that last from 20 to 30 minutes, and the meetings are presided over by the foreman or by a man designated by him. A permanent safety committee exists because it is felt that the intimate gathering each week brings out points and practices that the average plant committee would miss. At the first weekly meeting of the month, three men are appointed to inspect tools and three men are appointed to inspect goggles, shoes and general wearing apparel. The six men serve for one month and make regular reports at each weekly quarry department meeting. Our point is to endeavor to get each individual more personally interested in safety and we find that this method does create personal interest, because individual quarry employees are encouraged and urged to talk and give their views and opinions at the departmental meetings. In other words, it amounts to "personal participation" and we believe there is no better method of teaching safety.

3. Should there be a trained first-aid team composed exclusively of quarry men in the quarry? The answer to this question is obviously "yes" though we doubt if many quarries have such a team. Practically all of the men employed in our quarry had the U. S. Bureau of Mines first-aid training in 1942 but just how the majority of them would react in an emergency is questionable. The main importance of first-aid training for quarrymen is that quarries, as

1 Presented at Portland Cement Association Regional Safety Meeting in Birmingham, Alabama, March 7, 1944.

2 In the preparation of this paper, the author acknowledges the help of W. T. Dowdle, Quarry Foreman of Lone Star Cement Corporation, Birmingham, Alabama.

a rule, are somewhat remote from the plant and are not always quickly accessible to aid from other parts of the mill. It is important that first-aid training be given, but just as important that once learned, a regular routine of practice be worked out. Our experience has been that once a course of first-aid is learned, it is usually forgotten unless regular practice is kept up. Only six of the 83 plants had men in the quarry who had had first-aid training. "Standards for Safety in Quarry Operations", issued last year by the Cement and Quarry Section of the National Safety Council, stresses that all quarry employees should receive first-aid training and that they should be re-trained annually.

Alabama state law states that at least once every three years all operating supervisors and men in key positions shall be trained in first-aid.

4. A quarry practice about which all are not in accord is the question of whether or not to allow personnel to bring and carry metal objects and matches about the quarry.

Alabama law states that persons engaged in transporting explosives, loading blast drill holes, or handling explosives for any purpose, shall not be permitted to smoke or to use or carry any open lights.

The P. C. A. questionnaire revealed that a large number of the plants have no rules whatever against metal objects and matches and that the balance did have some rules—mostly no matches and no smoking.

We believe that an armed guard would be required to prevent all smoking in a quarry, but we believe that a "No Smoking" rule prohibiting smoking within a distance of 50 feet of explosive loading operations would not work a hardship on anyone.

5. The importance of having trucks, which are used for transporting explosives, specially equipped for this purpose was recognized by only half of the cement plants answering the P. C. A. questionnaire.

"Standards for Safety in Quarry Operations" devotes two pages to rules governing vehicles transporting explosives and Alabama laws regarding the vehicles are very strict. The fact remains that, explosives in many instances are handled carelessly after leaving the magazine.

The most popular method of mis-handling explosives being taken from the magazine seems to be in sliding the boxes onto a metal bed of a dump truck, or along the steel slats partially covering the bed of a stake body truck. Upon arrival of the cases of explosives at the scene of the shot, they are usually dropped about two feet to the ground.

The average quarry will use every precaution when transporting explosives on a public highway—possibly because of state laws—but will allow careless transportation in the confines of their own property.

It is a simple matter to make light wood, slatted false frames for the bottom and sides of the average truck for use when carrying explosives. These frames can usually be stored near the magazine or in the truck garage.

When a case of dynamite slides along a steel bottom truck, there is always the serious danger that a nail in the box will cause a spark, resulting in an explosion. It is especially dangerous when dynamite is old, and also in hot weather when the glycerin in the explosive is more likely to leak through the wooden containers.

6. The P. C. A. questionnaire asked the plants what precautionary measures were taken about men entering magazines and a variety of answers were given, but only half of the plants had any definite rules. It is presumed that common sense was the rule at the other plants which is probably all right for a lot of men, but there will always be one man who will eventually get careless. We believe that it would be a good idea to frame a set of rules and hang them in the magazines, the rules to include no smoking, no matches, no open light, using plastic case flashlights, and no opening of boxes in the magazine. This subject could well be brought up at the departmental meetings as a refresher from time to time, presuming of course that departmental meetings are held at the various plants.

7. The guarding of magazines by armed guards during war time is a subject that deserves serious consideration. All of you of course know that federal law requires that magazines be locked with the equivalent of two five tumbler padlocks, but during war time it would be well also to floodlight the magazine, carry only a quantity of explosives necessary to insure operations, build a magazine close to the plant proper where the watchman can make visits at not less than two hour intervals, and take daily inventory of explosives. Our company has done all of this since the war started, and in most cases it meant the building of new magazines and paying a premium for less than carload lots of dynamite.

8. Our plant does not use "springing shots" and of the 83 cement plants, replying to the P. C. A. questionnaire, only 8.4% do spring holes. The question was asked as to how long should a sprung hole be allowed to cool before reloading. "Standards for

Safety in Quarry Operations" states that time required for cooling varies with the size of the charge used and with the type of rock, and recommends that the temperature of the hole should be less than 80 degrees Fahrenheit and in case of a large springing shot, the hole should be allowed to cool until the following day. Alabama state law uses the 80 degree rule.

It would be impractical to take the temperature of each hole, and it seems that experience with temperatures of a few holes would give a time limit that could be arrived at eventually. A common sense and safe rule, however, would be to plan the operations so that at least a full day would intervene before reloading sprung holes.

9. It sometimes becomes necessary to stop loading before all holes have been loaded, and when this occurs, the question of the best and safest way of protecting the loaded holes against accidental firing arises.

Practically all plants answering the P. C. A. questionnaire had given this subject consideration and most of them had a reasonably safe method such as stemming the hole and protecting the primacord against dampness and against its being cut. Most of the plants indicated that their shots were planned so that they could be carried to completion promptly. Should it become necessary to stop loading at our quarry, we will stem the loaded holes, adequately protect the primacord, and make no connection whatever to the primacord in the hole. If possible, the vicinity of the shot will be floodlighted and the watchman instructed to go near the shot at about two hour intervals. Most important of all, the primacord will be cut at least two feet from the top of the hole and anchored in order to allow for the stemming to settle. If the stemming settles, it will of course carry the primacord with it unless precautions are taken to prevent this from happening.

10. The P. C. A. questionnaire summary revealed that all plants are not unanimous in their methods of loading ledge shots, insofar as dropping or lowering cartridges are concerned, because 22 plants drop while about 19 lower. Some plants drop in smooth holes and lower in rough and some lower at the start and then drop.

Three circumstances should govern the method of loading —(1) depth of holes, (2) strength of the dynamite and (3) roughness of the holes.

Powder representatives do not advise dropping cartridges up to 60% strength over 100 to 125 feet, and cartridges of 75% gelatin strength over 75 feet. Holes over 100 to 125 feet deep should be loaded by lowering. All rough holes should be loaded by lowering. Advocates of dropping argue that it would be impossible to get sufficient dynamite in the hole without dropping, because dropping (assuming the cartridge covering has been slit) compresses the load much better than tamping with a dolly. Advocates of slitting and dropping also contend that the speed of the falling cartridge is checked considerably if slit, because air enters the slit portion and tends to swell the cartridge like a balloon.

11. We now come to a very controversial question that can be discussed and argued about and still no set rules can be made. I refer to misfires or failure of the dynamite in a hole to explode.

We will first discuss misfires or failures in jackhammer holes when electric blasting caps are used. Of course, in secondary blasting there are more misfires than in primary blasting, but they are easier and simpler to handle because of the shallowness of the hole. After a secondary shot, the first man to return to the scene of the shooting should be the powderman, and he should check the shot for failures. If he finds a failure, he should first check the two lead wires with a galvanometer to determine whether or not the cap is good or bad. If the cap is good, the hole is re-shot in the usual manner. If the cap is bad, he should remove a portion of the stemming and insert a new primer and again shoot the hole. There are various ways of handling misfires on secondary blasting, and our experience has been that most quarrymen have adopted what they consider a safe method by experience and by consulting powder company representatives.

Misfires in well drill holes are a much more serious problem and deserve considerable study and thought. In primary blasting, possibility of a misfire should be provided for as each hole is loaded, by making a detailed chart of the dynamite and stemming in each hole. If a misfire should result, then the chart can be consulted, and from the chart the various depths of stemming and dynamite can be seen at a glance. The foreman or powderman thus has a picture of the conditions in the misfired hole, and this will prove invaluable when studying the best method of again firing the hole. Most essential is knowing the distance from the top of the hole to the charge of dynamite on top.

The danger of misfires will be considerably lessened if proper precautions are taken during the loading of the holes. By proper precautions is meant that after each charge of dynamite is placed in a hole

and tamped, the primacord should be examined and tested to see that it has not been broken. A simple test is to pull slightly on the primacord and to look in the hole with a mirror. Also, while stemming, one loader should hold the primacord in his hand and exert a gentle pull on it. If the primacord is broken by the falling stemming, the fact will be known immediately. A tamping dolly should be used as little as possible because there is danger of breaking the primacord with the dolly.

If the misfire was caused by a loose connection where a trunk line is connected to the main line primacord, and if there are no buildings or highways nearby, a blasting cap may be inserted on the end of the trunk line and the hole fired.

If the primacord is burned down into the stemming the stemming may be removed with a brass or copper spoon, but this must be done under the supervision of an experienced and capable foreman or powderman. By referring to the chart, removal of the stemming can be stopped within a few inches of the top charge of dynamite. After removal of the stemming, a new primer can be inserted and the hole again stemmed and fired.

It often happens that the charge of dynamite in a misfired hole is too deep to remove all of the stemming above it, and in this case it is safe to drill a new hole and depend on the firing of this new hole to set off the misfired one. The location of the new hole, that is, its proximity to the misfired hole, will depend on the structure of the rock. If the ledge is full of cracks and mud seams, the distance of the new hole from the old one should be such that the well drill bit will not contact dynamite that might have been tamped out into the cracks and mud seams. If the rock is firm and solid, the new hole can be drilled within about five feet of the misfired one. The safe distance to drill is a serious problem and should be determined only after weighing all known facts regarding the structure of the ledge.

Conclusion

In concluding this paper, we trust that at least some of our remarks have served to impress upon you the importance of safety in quarry operations. While you may not agree with all of the safe methods that we advocate, you can not fail to agree that there is no substitute for a wide awake and safety-minded foreman and a wide awake and safety-minded quarry organization. After all, the answer to quarry safety lies in the men themselves and in their application of common safety sense from day to day.

Some Field Observations on Industry Conditions

(Continued from page 17)

ministered by the Mining Division of WPB, the same priority ratings are accorded crushed stone producers for needed maintenance, repair and operating supplies, as to other essential mining activities. The difference in status as between critical or essential materials is determined by whether or not the supply of a given product is adequate to meet the full requirements of the military and essential civilian demands. Certainly the ability of crushed stone producers to meet the demands imposed by all the war activities without creating a critical condition in the supply of crushed stone is in reality a tribute to the wisdom and farsighted planning of management and plant operators of this industry.

No one will deny that crushed stone products being supplied for the following uses, which constitute the bulk of the output, were not essential to the successful prosecution of the war. Such uses include: Railroad ballast; fluxing stone for the steel, aluminum, and chemical industries; concrete and bituminous aggregates for use in building construction, naval dry docks, airports and highways, army camps, naval centers, and numerous other projects such as supply depots and industrial plants; filter stone for army camps; agricultural limestone for soil conditioning on millions of American food-growing acres; rock dusting material to safeguard the lives of coal miners against the hazards of underground explosions; and riprap for soil erosion prevention at strategic army and navy bases. While the exact tonnage shipped to each use is not available at the present time, the total for all uses of crushed and broken stone for the latest year for which records are available from the Bureau of Mines, covers the production for 1942, and according to this report, over 194,000,000 tons were produced. Serving all of these needs in quantities heretofore unthought of, and doing this in spite of the fact that it meant a severe strain on personnel and wear on plant facilities, means that the crushed stone industry came through along with other allied materials producers in making a contribution to the war effort of incalculable value.

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Excavating, Drilling and Material Handling Equipment

Cross Engineering Co.
Carbondale, Pa.
Screen Plates and Sections, Perforated Plate, for Vibrating, Rotary and Shaking Screens

Deister Machine Company
1933 East Wayne Street, Fort Wayne, Ind.
Deister Plat-O Vibrating Screen, Deister Compound Funnel Classifier

Diamond Iron Works, Inc.
Minneapolis, Minn.
Rock Crushing, Conveying and Transmission Machinery

E. I. du Pont de Nemours & Co., Inc.
Wilmington, Del.
Explosives and Blasting Accessories

Dymonhard Corporation of America
250 West 57th St., New York City
Hard Facing Welding Rods

Easton Car and Construction Co.
Easton, Pa.
Quarry Cars, Truck Bodies and Trailers
Electric Heaters for Tar, Asphalt or Bitumen

Ensign-Bickford Co.
Simsbury, Conn.
Cordeau-Bickford Detonating Fuse and Safety Fuse

Frog, Switch & Mfg. Co.
Carlisle, Pa.
Manganese Steel Department—Manufacturers of "Indian Brand" Manganese Steel Castings for Frogs, Switches and Crossings, Jaw and Gyratory Crushers, Cement Mill, Mining Machinery, etc., Steam Shovel Parts

MANUFACTURERS' DIVISION of the NATIONAL CRUSHED STONE ASSOCIATION

General Electric Co.
1 River Road, Schenectady, N. Y.
Electric Motors

Goodyear Tire & Rubber Co.
Akron, Ohio
Belting (Conveyor, Elevator, Transmission), Hose (Air, Water, Steam, Suction, Miscellaneous), Chute Lining (Rubber)

Gruendler Crusher and Pulverizer Co.
2915 N. Market St., St. Louis, Mo.
Rock and Gravel Crushing and Screening Plants, Jaw Crushers, Roll Crushers, Hammer Mills, Lime Pulverizers

Hayward Co.
50 Church Street, New York City
Orange Peel Buckets, Clam Shell Buckets, Drag Line Buckets, Electric Motor Buckets, Automatic Take-up Reels

Hendrick Mfg. Co.
Carbondale, Pa.
Perforated Metal Screens, Perforated Plates for Vibrating, Shaking and Revolving Screens; Elevator Buckets; Hendrick Vibrating Screens

Hercules Powder Co.
Wilmington, Del.
Explosives and Blasting Supplies

Illinois Powder Mfg. Co.
124 N. 4th St., St. Louis, Mo.
Gold Medal Explosives

Iowa Manufacturing Co.
Cedar Rapids, Iowa
Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Hot and Cold Mix Asphalt Plants, Stabilizer Plants, KU-BIT Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment.

Kennedy-Van Saun Mfg. and Eng. Corp.
2 Park Ave., New York City
Material Handling Machinery—Crushers, Pulverizers, Vibrating Screens

Kensington Steel Co.
505 Kensington Ave., Chicago, Ill.
Manganese Steel Castings, Dipper Teeth, Crawler Treads, Jaw Plates, Concaves and Hammers

Keystone Driller Co.
Beaver Falls, Pa.
Drills, Power Shovels

The King Powder Co., Inc.
Cincinnati, Ohio
Detonite, Dynamites, and Blasting Supplies

Koehring Co.
3026 W. Concordia Ave., Milwaukee, Wis.
Mixers, Pavers, Shovels, Cranes, Draglines, Dumptors, Traildumps, Mud-Jacks

Kotal Company
52 Vanderbilt Ave., New York City
KOTAL, the Waterproofing Agent for Aggregates that Improves Hot Mixes, Cold Mixes, Traveling Plant Mixes and Road Mixes of Bitumen

Lima Locomotive Works, Inc.
Shovel and Crane Division
1108 Lima Trust Bldg., Lima, Ohio
Power Shovels, Draglines and Cranes

Link-Belt Co.
300 West Pershing Road, Chicago, Ill.
Complete Stone Preparation Plants. Conveyors, Elevators, Screens, Washing Equipment, Speed-o-Matic Shovels—Cranes—Draglines and Power Transmission Equipment

Ludlow-Saylor Wire Co.
Newstead Ave. & Wabash R. R., St. Louis, Mo.
Woven Wire Screens and Wire Cloth of Super-Loy, Manga-Loy and all commercial alloys and metals

Mack Manufacturing Corp.
34st St. & 48th Ave., Long Island City, N. Y.
Trucks, Truck-Tractors of All Types and Capacity, Gasoline or Diesel Power Optional

Maguire Industries, Incorporated
Auto-Ordnance Division
1437 Railroad Avenue, Bridgeport, Conn.
Nostrip, Roctreet

Marion Steam Shovel Co.
Marion, Ohio
A Complete Line of Power Shovels, Draglines and Cranes

McLanahan & Stone Corp.
Hollidaysburg, Pa.
Complete Pit, Mine and Quarry Equipment—Crushers, Washers, Screens, Feeders, etc.

MANUFACTURERS' DIVISION of the NATIONAL CRUSHED STONE ASSOCIATION

The National Supply Co., Superior Engine Division
1401 Sheridan Ave., Springfield, Ohio
Diesel Engine Equipment

New Holland Machine Co.
New Holland, Pa.
Limestone Pulverizers; Jaw, Roll, and Hammer Crushers; Elevators; Revolving and Vibrating Screens; Dewaterers; Belt and Apron Conveyors; Conveyor Belting; V-Belts; V-Belt Drives; Engines; Electric Motors; Concrete Mixers with or without Power Lifts

Nordberg Mfg. Co.
Milwaukee, Wis.
Cone Crushers, Vibrating Screens, Diesel Engines, Steam Engines, Compressors, Mine Hoists, Underground Shovels, Track Maintenance Tools

Northern Blower Co.
65th St. South of Denison, Cleveland, Ohio
Dust Collecting Systems, Fans—Exhaust and Blowers

Northwest Engineering Co.
28 E. Jackson Blvd., Chicago, Ill.
Shovels, Cranes, Draglines, Pullshovels

Parsons Engineering Corp.
3599 E. 82d St., Cleveland, Ohio
Dust Collecting Systems: Fans, Hoods and Blow Piping

Pioneer Engineering Works, Inc.
1515 Central Avenue, Minneapolis, Minn.
Jaw and Roll Crushers, Vibrating and Revolving Screens, Scrubbers, Belt Conveyors, Traveling Grizzley Feeder

Pit and Quarry Publications
538 South Clark St., Chicago, Ill.
Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Concrete Manufacturer, Concrete Industries Yearbook

Robins Conveyors Incorporated
270 Passaic Avenue, Passaic, N. J.
Belt Conveyors, Bucket Elevators, Gyrex and Vibrex Screens, Feeders, Design and Construction of Complete Plants

Rock Products
309 West Jackson Blvd., Chicago, Ill.

Ross Screen and Feeder Co.
19 Rector St., New York City
Ross Patent Chain Feeders for Feed Control of All Sizes Rock, Ores, Gravel, etc.

Screen Equipment Co.
9 Lafayette Ave., Buffalo, N. Y.
SECO Vibrating Screens

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screen, Simplicity D'centegrator, Simplicity D'watering Wheel

Smith Engineering Works
E. Capitol Drive at N. Holton Ave., Milwaukee, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Stedman's Foundry & Machine Works
Aurora, Indiana
Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers

Stephens-Adamson Mfg. Co.
Aurora, Ill.
Belt Conveyors, Elevators, Feeders, Car Pullers, Screens, Skip Hoists, Complete Plants

Taylor-Wharton Iron & Steel Co.
High Bridge, N. J.
Manganese and other Special Alloy Steel Castings

The Texas Co.
135 E. 42nd St., New York City
Asphalts, Lubricating and Fuel Oils

The Thew Shovel Co.
Lorain, Ohio
Power Shovels, Cranes, Crawler Cranes, Locomotive Cranes, Draglines. Diesel Electric, Gasoline. 3/8 to 2-1/2 cu. yd. capacities

The Traylor Engineering & Mfg. Co.
Allentown, Pa.
Stone Crushing, Gravel, Lime and Cement Machinery

Trojan Powder Co.
17 N. 7th St., Allentown, Pa.
Explosives and Blasting Supplies

The W. S. Tyler Co.
3615 Superior Ave., N. E., Cleveland, Ohio
Wire Screens, Screening Machinery, Scrubbers, Testing Sieves and Dryers